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SILVER BOW CREEK

REMEDIAL INVESTIGATION FINAL REPORT
APPENDIX D, PART 3

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SILVER BOW CREEK REMEDIAL INVESTIGATION
DRAFT FINAL REPORT

HELENA, MONTANA 59620

AGRICULTURE INVESTIGATION

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PREFACE

Silver Bow Creek originates north of Butte, Montana and is a major tributary to the upper Clark Fork River. Mill tailings and other mining wastes in and near the creek contribute to substantial downstream contamination, particularly by potentially toxic elements: arsenic, cadmium, copper, lead, iron, and zinc. These elements and others were present in the mine ore and remain as by-products of the milling and smelting processes.

The history of mining in the Butte area began with the discovery of placer gold in Silver Bow Creek, in late summer of 1864. Several townsites and camps sprung up among the diggings. However, these operations were short-lived, and most of the miners left by 1869. Those who stayed began prospecting the quartz lode deposits of silver and the associated complex copper ores on the Butte Hill. Their efforts culminated in a silver rush, which began in the mid-1870's and revived the old camp. During that time world-class deposits of copper ore were identified. By 1881, Butte had become one of the nation's major mining centers; the district attained national dominance in copper mining by the mid-1890's and international prominence by the turn of the century. By 1915, Anaconda Copper Mining Company led the industry; but in 1980, in response to a depressed copper market, Anaconda closed all the underground mines and continued active mining only in the Berkeley Pit (established in 1955). In 1977, Anaconda became a subsidiary of Atlantic Richfield Company (ARCO). ARCO closed the Berkeley Pit in 1982 and the East Berkeley pit in 1983.

In addition to mining, various ore processing facilities also operated in the Butte area. The first two mills were erected in 1874 to smelt gold and silver. Ten years later, Marcus Daly, one of the founders of the Anaconda Company, built a copper smelter 27 miles west of Butte and planned the city of Anaconda. The Anaconda Smelter was moved to a new location in the city in 1900, and operated from 1903 to 1980.

The history of over 100 years of continuous mining and related activities changed the area's natural environment greatly. Early mining, milling, and smelting wastes were dumped directly into Silver Bow Creek and transported downstream to the Clark Fork River. In 1911, the first treatment pond was built by Anaconda Company near Warm Springs, Montana, to settle out wastes from Silver Bow Creek before the water was allowed to move on. In 1916 and 1959, two more treatment ponds began operation. Silver Bow Creek continued to receive raw mining and milling wastes until 1972, when a treatment plant was added to the Weed Concentrator in Butte. Creek contamination problems were compounded by urban and domestic sewage, wood products treatment plants, phosphate and manganese production facilities, and chemical factories.

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EXECUTIVE SUMMARY

The objective of the Agriculture Investigation was to evaluate arsenic, cadmium, copper, iron, manganese, lead, and zinc contamination of agricultural lands receiving irrigation waters from either Silver Bow Creek or the upper Clark Fork River. Historic contamination of these lands was partly due to the use of the waters for irrigation. This investigation was designed as a two-phased project; only Phase I, a reconnaissance-level effort, has been implemented. The implemented study used existing data and phone interviews to identify potentially contaminated sites. Soil and plant material sampling and analysis provided the basis for evaluation of the severity of contamination and its potential effects.

Sampled agricultural lands irrigated with water from Silver Bow Creek or the Upper Clark Fork River were found to be contaminated occasionally by metals. In some cases this contamination was so severe as to prevent plant growth and/or be a concern for livestock. The data suggests that approximately 5,400 acres of land have been affected by the use of these waters for irrigation.

A three-part approach for Phase II agricultural studies is recommended. These Phase II studies would improve demarcation of the contamination's areal extent, refine the assessment of the severity of contamination, and aid in feasibility study reclamation planning.

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1.0 INTRODUCTION

The objective of the Silver Bow Creek Remedial Investigation (SBC RI) is to determine the extent and severity of contamination within the Silver Bow Creek/Upper Clark Fork River system (See Map 1-1). Once the extent and severity of contamination within the site has been determined, the risk to humans and selected environmental components can be assessed, and feasibility studies to develop remedial actions can be completed.

The Silver Bow Creek system has been contaminated by over 100 years of mining, mineral concentration (milling), and smelting activities within the basin. Contaminants of concern are arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn). These metals are found within the system at various concentrations, in various forms, and often well above geochemical background levels. The major sources of these contaminants are mill tailings deposits and contaminated ground water (See SBC RI Surface Water Investigation and Ground Water Investigation Reports, Appendices A and B). A timeline showing significant historical events that impacted Silver Bow Creek and the upper Clark Fork River is shown in Figure 1-1.

To evaluate potential risk, the migration of site contaminants into crops and animals consumed by humans needed to be determined during the RI. On the Silver Bow Creek site, three investigations were performed to allow this evaluation:

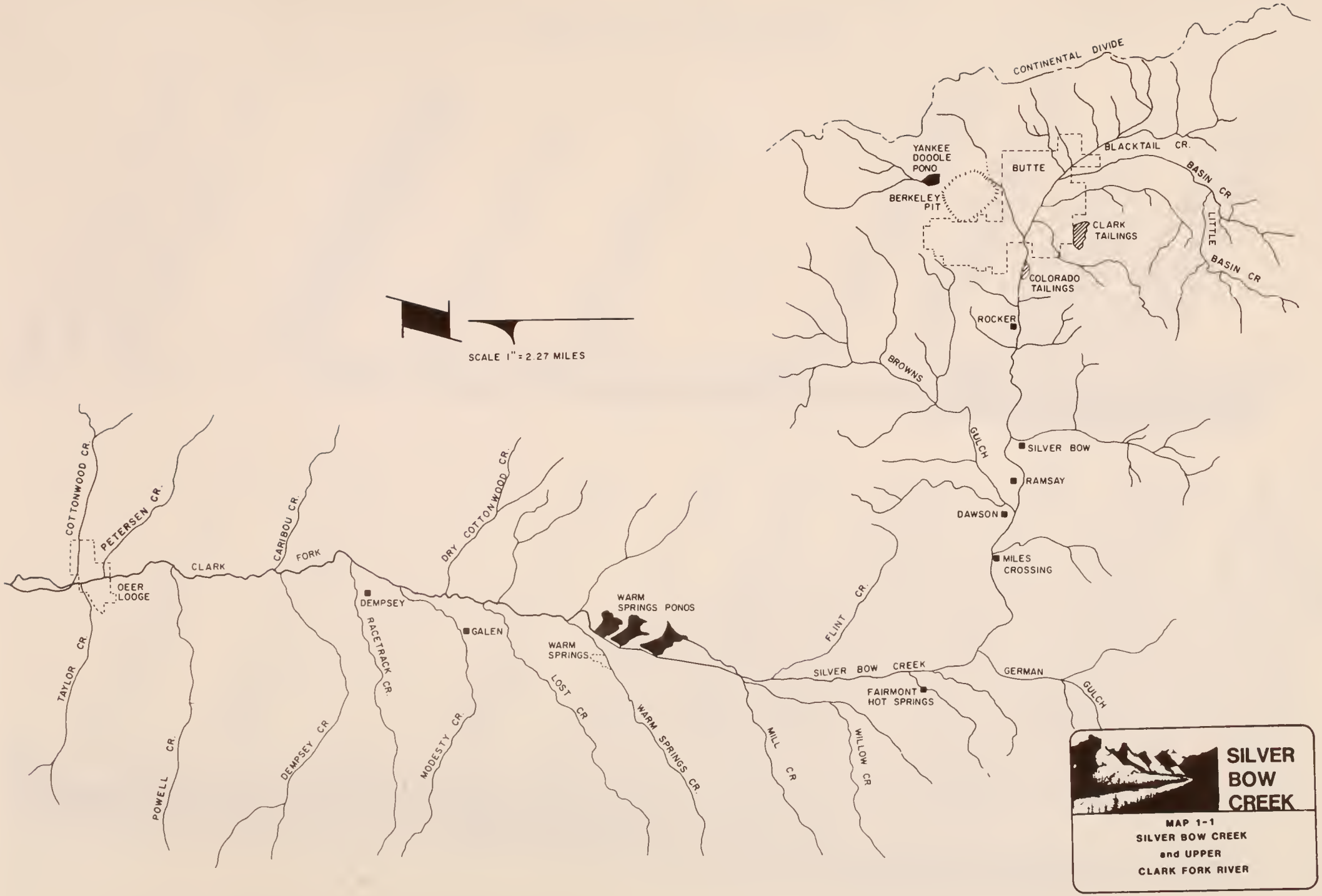
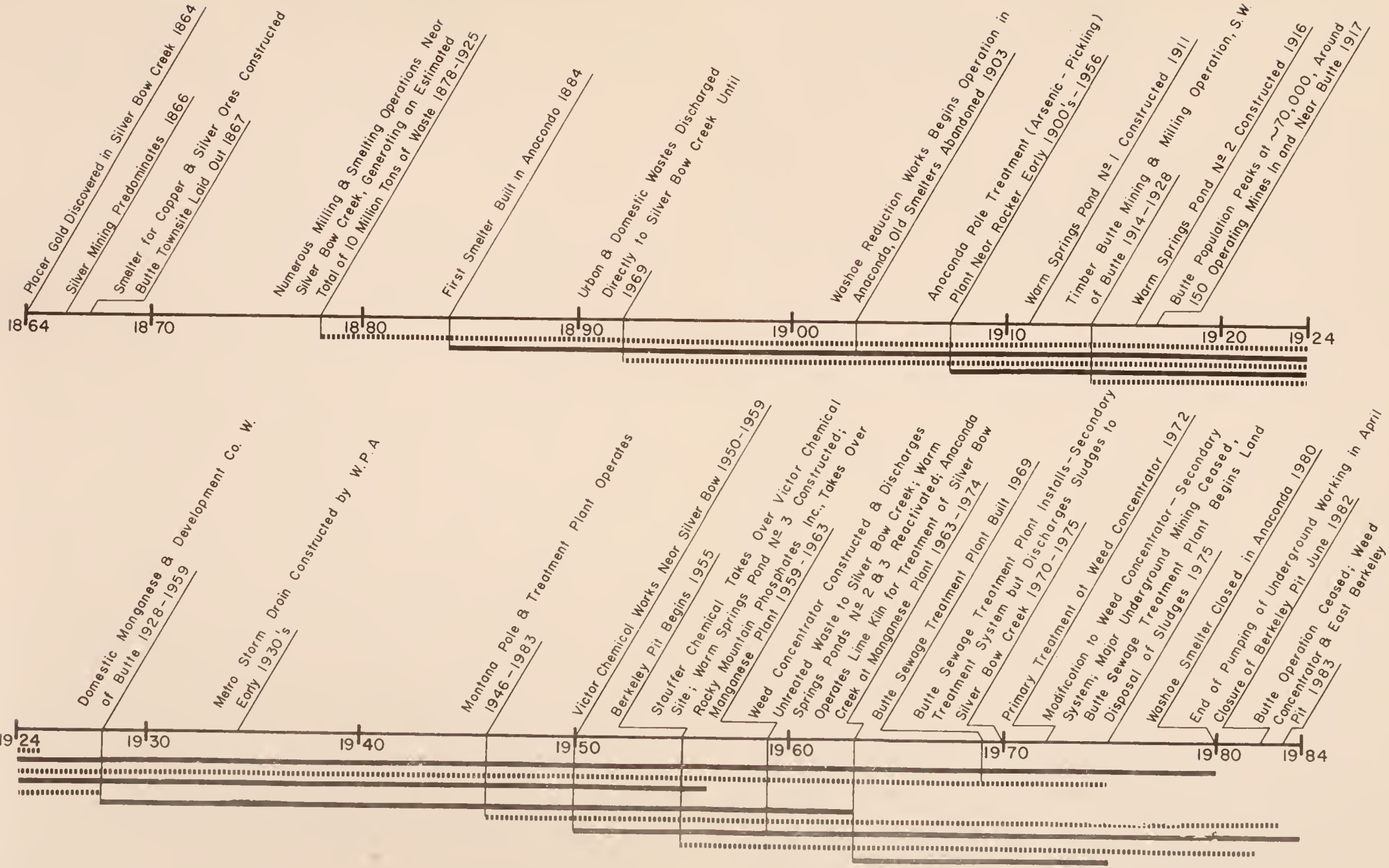

CONTINENTAL DIVIDE
YANKEE DOODLE PONO
BERKELEY PIT
BUTTE
BLACKTAIL CR.
BASIN CR
LITTLE BASIN CR
CLARK TAILINGS
COLORADO TAILINGS
ROCKER
BROWNS GULCH
SILVER BOW
RAMSAY
DAWSON
MILES CROSSING
SCALE 1" = 2.27 MILES
COTTONWOOD CR.
PETERSEN CR.
CLARK FORK
CARIBOU CR.
DRY COTTONWOOD CR.
OEER LODGE
DEMPSEY
GALEN
WARM SPRINGS PONOS
WARM SPRINGS
RACETRACK CR.
MODESTY CR.
LOST CR
WARM SPRINGS CR.
FLINT CR.
SILVER BOW CREEK
FAIRMONT HOT SPRINGS
GERMAN GULCH
MILL CR
WILLOW CR
TAYLOR CR.
POWELL CR.
DEMPSEY CR
SILVER BOW CREEK
MAP 1-1
SILVER BOW CREEK
and UPPER
CLARK FORK RIVER

FIGURE 1-1

HISTORIC CONTAMINATION OF SILVER BOW CREEK


Placer Gold Discovered in Silver Bow Creek 1864
Silver Mining Predominates 1866
Smelter for Copper & Silver Ores Constructed
Butte Townsite Laid Out 1867
Numerous Milling & Smelting Operations Near Silver Bow Creek, Generating an Estimated Total of 10 Million Tons of Waste 1878-1925
First Smelter Built in Anocondo 1884
Urbon & Domestic Wastes Discharged Directly to Silver Bow Creek Until 1969
Washoe Reduction Works Begins Operation in Anaconda, Old Smelters Abandoned 1903
Anoconda Pole Treatment (Arsenic - Pickling) Plant Near Rocker Early 1900's - 1956
Warm Springs Pond No 1 Constructed 1911
Timber Butte Mining & Milling Operation, S.W. of Butte 1914-1928
Warm Springs Pond No 2 Constructed 1916
Butte Population Peaks at ~70,000, Around 150 Operating Mines In and Near Butte 1917
1864
1870
1880
1890
1900
1910
1920
1924
Domestic Manganese & Development Co. W. of Butte 1928-1959
Metro Storm Droin Constructed by W.P.A Early 1930's
Montana Pole & Treatment Plant Operates 1946-1983
Victor Chemicol Works Near Silver Bow 1950-1959
Berkeley Pit Begins 1955
Stauffer Chemical Takes Over Victor Chemical Site; Warm Springs Pond No 3 Constructed; Rocky Mountain Phosphates Inc., Takes Over Manganese Plant 1959-1963
Weed Concentrator Constructed & Discharges Untreated Waste to Silver Bow Creek; Warm Springs Ponds No 2 & 3 Reactivated; Anaconda Operates Lime Kiln for Treatment of Silver Bow Creek at Manganese Plant 1963-1974
Butte Sewage Treatment Plant Built 1969
Butte Sewage Treatment Plant Installs-Secondary Treatment System but Discharges Sludges to Silver Bow Creek 1970-1975
Primary Treatment of Weed Concentrator 1972
Modification to Weed Concentrator-Secondary System; Major Underground Mining Ceased; Butte Sewage Treatment Plant Begins Land Disposal of Sludges 1975
Washoe Smelter Closed in Anaconda 1980
End of Pumping of Underground Working in April Closure of Berkeley Pit June 1982
Butte Operation Ceased; Weed Concentrator & East Berkeley Pit 1983
1924
1930
1940
1950
1960
1970
1980
1984

- Fish Tissue Investigation;
- Waterfowl Investigation; and
- Agricultural Investigation.

This report documents the findings of the Agricultural Investigation.

1.1 STUDY PLAN DEVELOPMENT

An RI-related literature review revealed an estimated 5,380 acres of potentially contaminated cropland within Silver Bow, Deer Lodge, and Powell Counties (MultiTech and Stiller and Associates 1984a). The suspected source of cropland contamination was the use of metal-laden water from Silver Bow Creek and the upper Clark Fork River for irrigation. The severity of contamination and consequent economic significance were not estimated.

Four concerns developed during the literature review:

- Whether the areal extent and severity of contamination had abated over time;

- Whether residual contaminants were present at sufficient levels to adversely affect the terrestrial food chain, and consequently become a threat to human health and welfare;

- Whether the irrigated lands also were affected adversely by deposition of heavy metal-laden particulate matter from smelter stack emissions; and

- The need for baseline physical and chemical data to evaluate alternative soil treatment and crop/livestock management practices (MultiTech and Stiller and Associates 1984b).

These four concerns determined the objectives of the Agricultural Investigation. The investigation was designed as a two-phased approach (MultiTech and Stiller and Associates 1984a):

- Phase One--a reconnaissance level effort to refine the preliminary estimate of extent of heavy metal contamination, plus a preliminary evaluation of the severity of such contamination on irrigated croplands, to livestock, and to human health and welfare;

- Phase Two--a statistically rigorous evaluation of the effects on agricultural production and/or human health found in Phase One, if approved by MDHES project management.

However, only Phase One has been implemented and is reported in this document. The first phase was divided into the following tasks:

- Task One--utilize existing data and phone interviews to identify land-owners who either knew or strongly suspected

adverse agricultural impacts resulting from the use of Silver Bow Creek and/or Clark Fork River waters; and

- Task Two--collect and analyze soil and plant materials from affected and adjacent control sites with no previously set levels of statistical confidence or sampling precision.

Numerically reduced laboratory data were analyzed statistically and spatially, and compared against environmental assessment criteria (MultiTech and Stiller and Associates 1984a) to address the first three concerns developed during the literature review. The fourth concern was addressed through the analysis of such reclamation-related parameters as plant macronutrient and plant-available heavy metal levels. These analyses were performed for those sites probably affected by exposure to contaminated irrigation water, as well as upgradient control sites. Results are presented in Section 3.0.

1.2 HISTORICAL DATA

The few studies performed early in this century documented locally adverse effects on irrigated lands situated adjacent to the Clark Fork River and throughout the Deer Lodge Valley (Haywood 1910; Batemen and Wells 1917). A more detailed discussion of these studies is presented in Section 4.4.2 of the Work Plan (MultiTech and Stiller and Associates 1984a). These investigations gave only cursory treatment to the extensive irrigation ditch system, despite concurrent evidence of mining-related impacts occurring elsewhere (Griffith 1919).

The continued presence of heavy metal contamination of riparian soils and vegetation, located within the Grant-Kohrs Ranch National Historic Site, has been demonstrated by Rice and Ray (1984). Their conclusions pertaining to the SBC RI are as follows:

- Copper, arsenic, and cadmium concentrations within the upper 25 cm. (10 in.) of the riparian soils are 10 to 100 times greater than for similar soils from areas lacking major sources of man-caused pollution;

- The deposition of these "heavy metals" - contaminated sediments on the Clark Fork River floodplain is the predominant and continuing mechanism of contamination;

- The probable source of these contaminants (at the ranch site) are upstream mining and smelter operations;

- Copper, arsenic, and (infrequently) cadmium levels in riparian vegetation are often elevated several-fold above "expected" levels; and

- Acute livestock toxicity does not appear to be of any risk anywhere on the ranch.

An extensive review of heavy metal air pollution effects on agriculture within the Deer Lodge Valley can be found in Section 1.1 of the Anaconda Smelter soils/cropland study plan prepared by Multi-Tech and Native Plants, Inc. (1984). The historical data were inadequate to answer concerns of the Agricultural Investigation.

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2.0 METHODS

2.1 LOCATION OF SAMPLING STATIONS

Landowners potentially affected by the use of Silver Bow Creek or Clark Fork River waters for agricultural purposes were interviewed by phone between December 3, 1984 and February 4, 1985. The survey is described in the Silver Bow Creek Remedial Investigation Work Plan (MultiTech 1984a); the completed interview records are stored in MultiTech's project files. Two memoranda that summarize the Task One findings are found as Attachments I and II to this report (Cornish 1984, 1985).

Eight candidate sites (Cornish 1985, Table 1) were inspected and interviews subsequently were conducted with landowners of the most promising sites, during the period June 24 through June 28, 1985. The Hollenback site was elminated, as site-specific "control" samples were taken along with "contaminated" samples. Originally, the Hollenback site was to serve as a "regional control site", for the entire RI study area.

Two sites were added to those identified in the Work Plan: the Thurmond and Dutton sites. Thurmond contacted MultiTech personnel on June 25 and expressed concern regarding damage to an irrigation pipe as a result of using Silver Bow Creek water. Sampling at Dutton's wet meadow proved valuable, as a buried tailings deposit was discovered despite the general presence of lush hydrophytic (water-loving) vegetative cover.

Those sites not exhibiting the Work Plan's "site avoidance" criteria, and consequently sampled for soils and plant materials, are shown in Table 2-1. Approximate site locations are shown on Map 2-1; detailed site descriptions are provided in Section 3.0. Claims of livestock deaths resulting from heavy metals poisoning were noted during the phone interviews (Cornish 1984, Table 1). However, livestock tissue sampling was postponed until soils and plant material laboratory data could be evaluated for the presence of significantly elevated or known toxic levels of the selected contaminants in accordance with the Work Plan.

2.2 SAMPLE COLLECTION

2.2.1 Soils Sampling

During the Phase One (Reconnaissance) efforts, 38 soil samples were taken at 16 sites. With the exception of the Dutton site (A9), samples were taken above ("upgradient") and below ("downgradient") abandoned--and often times breached--irrigation ditches. Table 2-2 presents sampling dates, sampling depths, and field identification numbers. Additional site information is found in Table 2-1, while approximate site locations are shown in Map 2-1. Five sets of duplicate samples and two DI water blanks constitute the QA/QC field efforts.

The methodologies utilized were modified somewhat from those described in the Work Plan, either for matters of practicality or

TABLE 2-1
PHASE ONE AGRICULTURAL SAMPLING SITE LOCATIONS
(IN DOWNSTREAM ORDER)

Landowner's Name or Contact Person	Site Designations	Sampling Site Location[a],[b]
Robert Thurmond	A10	T3NR8W20DADB
	A11	T3NR8W20BCAB
Walter Konda	A1	T3NR9W16CBCB
	A2	T3NR9W16CBCB
	A3	T3NR9W16DCCB
William Peterson	T12	T4NR10W35CDDD
	T13	T4NR10W35DDDD
	T14	T4NR10W35CADB
	T15	T4NR10W35DADB
	T16	T4NR10W35ABBA
	T17	T4NR10W35CBBA
Hazel Spangler	A6	T4NR9W30ACAB
	A7	T4NR9W30CCAB
Lovell Ranch/Dick Forsen	A12	T7NR9W16AADA
	A13	T7NR9W16AADA
Dave and Dean Dutton	A9	T10NR10W31ACBA

(a) Sites located to the nearest 2.5 acres using the counterclockwise demarcation system used by the USDI BLM (e.g., A= northeast quadrant).

(b) Site location determined by inspection of variously scaled aerial photography and topographic maps.

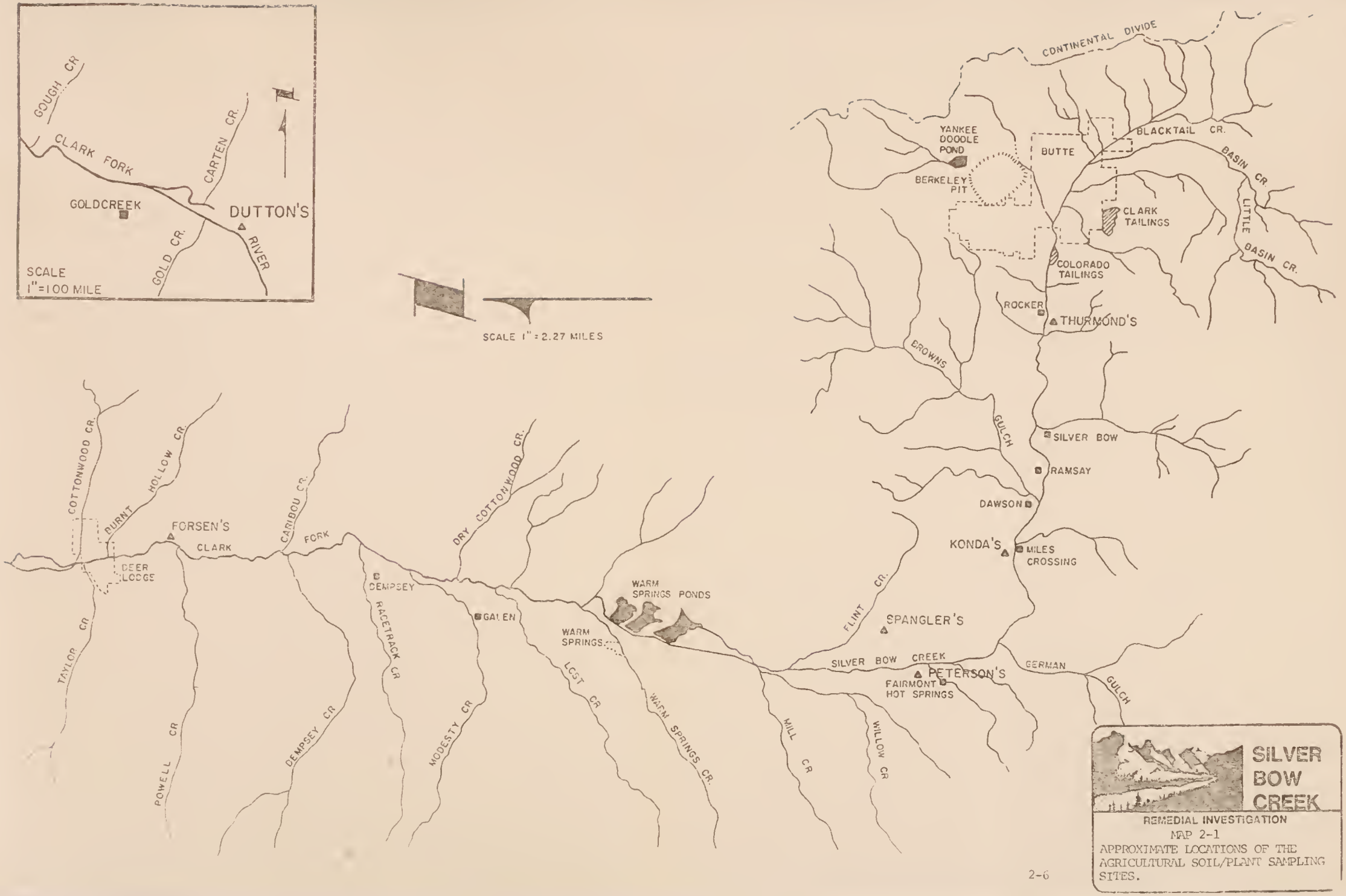
TABLE 2-2
SOIL SAMPLING FIELD DATA
(IN DOWNSTREAM ORDER)

Sampling Site No.	Sampling Dates	Sampling Depth (in.)	Field No.	Comments[a]
A10	6/27/85	0-5	A10-5	Probable control site.
A11	6/27/85	0-9	A11-6	Suspected tailings contaminated site adjacent to Silver Bow Creek.
A1	6/27/85	0-12	A1-7	Above Miles Ditch (probable control site).
		12-22	A1-8	
		22-28+	A1-9	
A2	6/27/85	0-6	A2-10	Just below Miles Ditch (possibly contaminated by overflow/sediment).
A3	6/27/85	0-15	A3-11	Salt affected?
		15-30	A3-12	Mill tailings noted.
		30-46	A3-13	---
T12	6/28/85	0-5	T12-59	Above old lateral ditch (fed by the Yellow Ditch); possible control site.
		5-17	T12-60	
T13	6/28/85	0-3	T13-61	Possible overflow (contaminated) area below old lateral ditch.
		3-10	T13-62	
		10-18	T13-63	
T14	6/28/85	0-4	T14-55	Probably contaminated (bare) ground alongside an old lateral of the Yellow Ditch.
T15	6/28/85	0-8	T15-56	Plow layer taken near chlorotic oats.
T16	6/28/85	0-4	T16-57	Bare ground near lateral ditch (from Yellow Ditch) at "lower field".

TABLE 2-2
SOIL SAMPLING FIELD DATA (Continued)
(IN DOWNSTREAM ORDER)

Sampling Site No.	Sampling Date	Sampling Depth (in.)	Field No	Comments[a]
T17	6/28/85	0-5	T17-58	Grab sample from above lateral ditch (possible control site).
	6/28/85	N/A[b]	Field Blank	DI HOH from laboratory.
A6	7/06/85	0-5	A6-18	Suspected as being
		5-12	A6-19	minimally contaminated
		12-24	A6-20	(possible control site).
A7	7/06/85	0-5	A7-14	Appears to have been
		5-15	A7-15	contaminated by breached
		15-25	A7-16	irrigation ditch water/
		25-37	A7-17	sediment.
A12	7/07/85	0-5	A12-21	Above E. Valiton Ditch (probable control site).
		5-14	A12-22	Duplicate sample taken, (i.e., T-77)
		14-40	A12-23	Duplicate sample taken, (i.e., T-78).
A13	7/03/85	0-4	A13-98	Duplicate samples taken
		0-4	A13-99	below the E. Valiton Ditch.
	7/07/85	0-3	A13-24	Duplicate sample taken (i.e., T-79).
		3-8	A13-25	Duplicate sample taken, (i.e., T-80).
		8-18	A13-26	---
		18-38	A13-27	---
A9	6/26/85	0-5	A9-1	Mucky soil.
		5-10	A9-2	Mucky soil.
		10-18	A9-3	Mill tailings/sediment.
		18-26	A9-4	Buried "A" horizon.
	6/26/85	N/A[b]	Field Blank	DI HOH from laboratory.

(a) Comments taken from field notes.
(b) N/A means Not Applicable.


GOUGH CR
CLARK FORK
CARTEN CR.
GOLDCREEK
DUTTON'S
GOLD CR.
RIVER
SCALE
1"=100 MILE
SCALE 1" = 2.27 MILES
CONTINENTAL DIVIDE
YANKEE DOODLE POND
BERKELEY PIT
BUTTE
BLACKTAIL CR.
BASIN CR
LITTLE BASIN CR.
CLARK TAILINGS
COLORADO TAILINGS
ROCKER
THURMOND'S
BROWNS GULCH
SILVER BOW
RAMSAY
DAWSON
KONDA'S
MILES CROSSING
FLINT CR.
SPANGLER'S
SILVER BOW CREEK
PETERSON'S
FAIRMONT HOT SPRINGS
GERMAN GULCH
WILLOW CR
MILL CR
WARM SPRINGS CR.
LOST CR
WARM SPRINGS
WARM SPRINGS PONDS
GALEN
DEMPSEY
RACETRACK CR
MODESTY CR
DEMPSEY CR
POWELL CR
TAYLOR CR
DEER LODGE
FORSEN'S
CLARK FORK
CARIBOU CR.
DRY COTTONWOOD CR.
BURNT HOLLOW CR.
COTTONWOOD CR.
SILVER BOW CREEK
REMEDIAL INVESTIGATION
MAP 2-1
APPROXIMATE LOCATIONS OF THE AGRICULTURAL SOIL/PLANT SAMPLING SITES.

for improved integrity of results. The major changes are presented below:

- The data originally planned for inclusion in the field sample record book and accompanying field diary were collected, but are not contained in these two documents. All of this information currently is stored in MultiTech's project files.

- Horizon-specific bulk samples from one soil pit per site were taken using a sharpshooter spade, trowel, and dish; this approach replaced the planned method of composite sampling at predetermined depth intervals within a marked 0.1 acre plot. The method utilized provided more useful information and yet met the investigation's original objectives. In accordance with the QA/QC plan, two soil pits were dug and sampled at those sites requiring field duplicates (MultiTech and Stiller and Associates 1985).

- The sample collection tags utilized did not contain an analyses required section. These requests were specified on the sample-specific analytical request forms completed at time of transfer-of-custody to sample bank personnel.

2.2.2 Vegetation Sampling

During the Phase One (Reconnaissance) efforts, 18 plant samples were collected at 16 sites. Table 2-3 presents sampling dates, species (or genus) sampled, and field identification numbers. Additional site information is found in Table 2-1, while site locations are shown approximately in Map 2-1. In accordance with field QA/QC requirements, one set of duplicate samples and one DI water blank were collected (MultiTech and Stiller and Associates 1985).

The methodologies utilized were modified somewhat from those described in the Work Plan; such changes were based largely on practical considerations and had no adverse effect on the integrity of the investigations. The major changes are as follows:

- Plant material was sampled randomly within 0.1 acre plots having the initial soil pit as its origin; the use of four approximately 1 sq.ft. plots per site was rejected on the grounds of inadequate biomass gathered. Vegetation sampling occurred concurrently with soil pit excavation and sampling.

- Given the drought conditions, plant materials were not always sampled at probable time of maximum protein content, as specified in the Work Plan. However, protein content was probably approaching this maximum, as indicated by the

TABLE 2-3
VEGETATION SAMPLING FIELD DATA
(IN DOWNSTREAM ORDER)

Sampling Site No.	Sampling Date	Sample Taxonomy	Field No.	Comments[a]
A10	6/27/85	POPR	A10-1	Kentucky bluegrass growing on probable control site.
A11	6/27/85	CAREX	A10-2[b]	Unidentified sedge species (possibly C. nebraskensis) on suspected tailings contaminated site adjacent to Silver Bow Creek.
A1	6/27/85	AGSP	A1	Bluebunch wheatgrass at probable control site.
A2	6/27/85	CAREX	A2	Unidentified sedge species (possibly C. stenophylla) on possibly contaminated site.
A3	6/27/85	ELCI	A3-1	Basin wildrye and unidentified sedge species (possibly C. nebraskensis) on probably contaminated site.
		CAREX	A3-2	
T12	6/28/85	CAREX	T-12	Unidentified sedge species (possibly C. stenophylla) on possible control site.
T13	6/28/85	CAREX	T-13	Unidentified sedge species (possibly C. stenophylla) on probably contaminated site.
T14	6/28/85	MESA	T-14	Alfalfa sampled adjacent to bare ground along an old lateral of the Yellow Ditch, and presumed to be contaminated.
T15	6/28/85	AVSA	T-15	Chlorotic oats (possibly Zn-induced Cu deficiency).

TABLE 2-3
VEGETATION SAMPLING FIELD DATA (Continued)
(IN DOWNSTREAM ORDER)

Sampling Site No.	Sampling Date	Sample Taxonomy	Field No	Comments[a]
T16	6/28/85	MESA	T-16	Same as for T-14.
T17	6/28/85	MESA	T-17	Alfalfa sampled from above the lateral ditch, and possibly a control site.
	6/28/85	N/A[c]	Field Blank	DI HOH from laboratory.
A6	7/03/85	ELCI	A6-1	Duplicate samples of Basin wildrye taken at a possible control site.
		ELCI	A6-2	
A7	7/03/85	ELCI	A7	Basin wildrye from probably contaminated site.
A12	7/03/85	ELCI	A12	Basin wildrye taken from above the E. Valiton Ditch, and probably a control site.
A13	7/03/85	ELCI	A13	Basin wildrye taken from below the E. Valiton Ditch, and slightly north of the soil sampling sites in probably contaminated ground.
A9	6/26/85	BRIN	A9	Smooth brome taken at Dutton's buried mill tailings site.

(a) Comments taken from field notes.
(b) Minor error in sample labeling, but definitely acquired at site A11.
(c) N/A means Not Applicable.

following species phenologies: alfalfa crops were beginning to bloom while grass (e.g., Basin wildrye) and grass-like (Carex) species were forming fruiting bodies. The one exception to this assumption is with oats, which were sampled in the "boot" stage of development. Finally, the sites selected for sampling did not include potatoes, so this crop was not sampled.

- Although 250-400 grams of fresh, washed, biomass were taken for each species at each site, seedheads/fruiting bodies were not separated from the vegetative portions (i.e., stems and leaves). The rationale for this change is that no mature grain crops were sampled; rather, the plant materials sampled were in the same form as would be consumed by livestock and wildlife species.

2.3 SAMPLE PREPARATION

All soil, vegetation, and field QA/QC samples submitted to the sample bank were processed in accordance with QA/QC plan requirements (MultiTech and Stiller and Associates 1985). Pertinent information was transferred from the chain-of-custody sheets and analytical request forms to the sample bank's master log book.

2.3.1 Soils

In many cases, the dried and sieved sample's weight was insufficient to justify splitting into three separate containers as planned (MultiTech and Stiller and Associates 1984a). Consequently, the processed samples were bulked in plastic sacks and stored in the sample bank until needed for analysis. The physicochemical analyses were performed using the -2mm mesh fraction, including the material utilized for the nitric acid/hydrogen peroxide digest prior to total trace element determinations.

2.3.2 Vegetation

Following log-in, all samples were transferred immediately to a forced-draft oven set at 40± 1°C. They remained there until clearly dry in appearance, but never for periods exceeding 48 hours. The dried samples then were ground and prepared in accordance with the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a).

2.4 SAMPLE ANALYSIS

The soils and plant samples were analyzed by standard or common methods as much as possible; however, some analyses required methodological development by MultiTech personnel. Standard, or commonly utilized, methods are largely incorporated by reference. Less common methods are described thoroughly. Overviews are presented

in the main text, while technical details are relegated to Attachments III and IV for soils and vegetation, respectively.

2.4.1 Soils

2.4.1.1 pH

The 20g:20mL soil:DI water suspensions (in 50 mL plastic beakers) were stirred intermittently for approximately 1 hr prior to pH measurement; each suspension was stirred well (magnetically) immediately prior to inserting the glass electrode. The instruments used included an Orion Research® pH/SIE meter (model 701A) or a Markson® digital pH meter(model 88). The meters used were recalibrated using pH 4.0 and/or 7.0 standards at a frequency of 1:10. If significant deviations (i.e., $\geq$ 0.2 units) occurred, the previous set was reanalyzed.

2.4.1.2 Electric Conductivity (EC)

EC was determined on each sample's saturated paste extract (see Section 2.4.1.4) using a Sybron/Barnstead® conductivity bridge (model PM-70CB) and a Beckman® small volume conductivity cell (model 0731 DH). Measurements were performed in accordance with the instrument's instruction manual. The cell constant was calculated using those procedures described in the APHA's (1980) Standard Methods.

2.4.1.3 Mechanical Analysis

The percent (w/w) sand, silt, and clay contained in the unknowns and QA/QC samples were determined using a slightly modified version of the hydrometer method found in Sobek et al. (1978). This approach, developed originally for analyzing mine soils and overburden, generates data required to meet project objectives. Furthermore, the data are produced at a quicker rate than the ASTM Method D422-63 ("Particle-Size Analysis of Soils"). Technical details for the approach utilized are given in Attachment III.

2.4.1.4 Saturation Paste Extract and Saturation Percentage

The soil paste saturation extract procedures utilized are described in USDA Handbook No. 60 (Richards et al. 1954). The extracts were pressure-filtered through Nalgene® disposable filter disks (0.45 μm) connected to a 50 mL. capacity syringe/plunger system. After withdrawing several mL of the filtrate for the EC measurement, the remaining volume was acidified (1% v/v) with AR-grade nitric acid. The sample volumes were stored in polyethylene bottles in the sample bank prior to AAS analysis for Na, K, Ca and Mg.

Saturation percentage was calculated from oven-drying data, using that formula described in Richards et al. (1954).

2.4.1.5 Trace Element Plant Available Estimates

The extraction system utilized to estimate trace element plant availability was determined by sample pH. If the pH was $\geq$ 7, a DTPA extraction was used (Lindsay and Norvell 1978). If the pH was <7, freshly prepared 1N ammonium acetate, adjusted to pH 5.5 with ARgrade glacial acetic acid, was utilized (Knudsen et al. 1982). The following modifications to the Lindsay and Norvell method were made:

- The quantities of soil and extractant were doubled (i.e., to 20 gm soil and 40 mL DTPA solution) to provide adequate sample volume for spectrometric analysis;

- Each flask's solid contents were not completely washed into the filter, nor were the filtrates diluted to some standard volume, as these steps would result in an uncontrolled dilution effect; and

- Each filtrate was preserved with 0.250 mL. AR-grade concentrated HNO_3, then refrigerated in polyethylene bottles prior to ICP or AAS quantitation.

The requisite QA/QC samples, including an EPA municipal sludge (#1159), were treated in the same manner as the unknowns.

2.4.1.6 Strong Acid Digestable Trace Element Analyses

The USEPA nitric acid/hydrogen peroxide wet ashing procedure was generally utilized, as described in Tetra Tech's (1984) Laboratory Analytical Protocol. However, the following modifications were made:

- Air-dried materials were ashed in 125 ml Erlenmeyer flasks with reflux caps inserted; and the

- Filtered digests were diluted to 50 ml standard volume, so as to minimize a second round of digesting for furnace AAS analysis.

In those cases where an element's concentration was below the flame AAS/ICP instrumental detection limits, the digestions were repeated without utilizing the HCl reflux step. The requisite QA/QC samples, including NBS Estuarine Sediment (SRM 1646) and USEPA municipal sludge (#1159) were handled in the same manner as the unknowns.

2.4.1.7 Plant Available Arsenic Analysis

In accordance with the USEPA's request (Bishop 1985), the plant-available arsenic was determined using a modified version of the Halvorson method. Variations from the method received from the USEPA are given below:

- The quantities of soil and extractant (concentrated AR-grade HCl) were doubled (i.e., to 4.00 gm soil and 20.0 ml acid);

- As ICP spectroscopy was utilized (rather than hydride generation/AAS), the extracts were initially centrifuged at 2000 rpm for 30 min, 20°C) and the supernatant volume withdrawn, then measured to the nearest 1.0 mL;

- Sufficient DI water was added to accomplish a four-fold sample dilution; and

- To avoid plugging the aspirator, the diluted samples were pressure-filtered through a Nalgene® 0.45 µm filter membrane with the filtrates being collected in 3 oz. polyethylene bottles.

As ICP spectroscopy determines total arsenic, a conversion of As(V) to As(III) was not necessary; consequently, no KI reductant solution was added to any of the extracts. The pertinent QA/QC samples, including USEPA municipal sludge (#1691) were handled in the same manner as the unknowns.

2.4.1.8 Extractable Arsenic and Phosphorus Analyses

The extractant system utilized to determine these parameters was pH-dependent. If sample pH was $\geq$7, the Olsen method was utilized (Olsen

and Sommers 1982). However, if the pH was <7, the Bray method was used (Olsen and Sommers 1982). The analytical scheme is shown in Figure 2-1. Soluble arsenic was determined using hydride generation/AAS. Soluble phosphorus levels were determined by spectrophotometric measurement of the 660 nm absorbing phospho-paramolybdate complex or by ICP. The pertinent QA/QC samples were treated in the same manner as the unknowns.

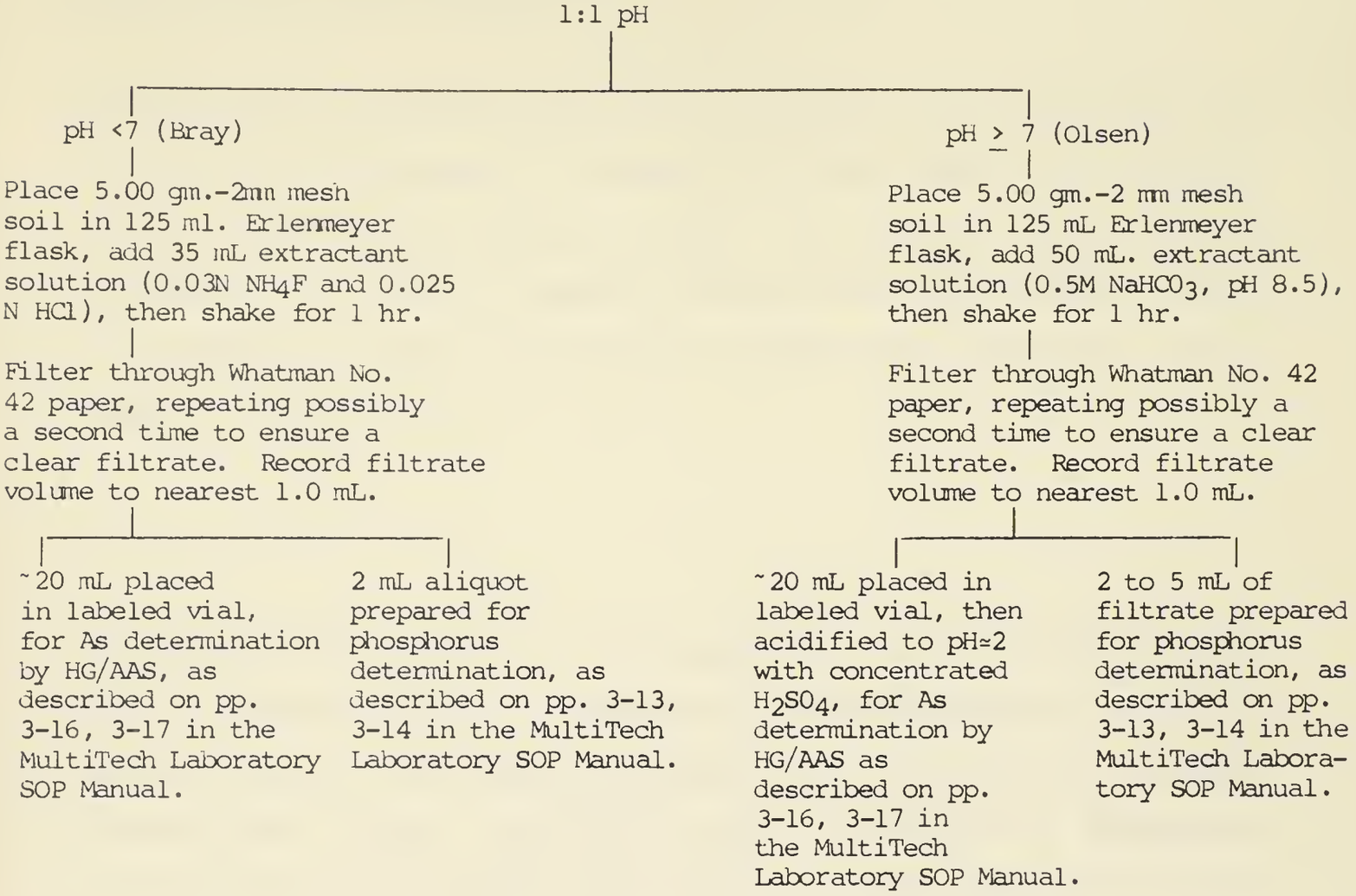
2.4.1.9 Nitrate Ion

A 20 gm soil:40 mL DI water suspension was prepared and treated as described in Keeney and Nelson (1982). The suspension was filtered through Whatman No. 42 paper, and the Orion® specific ion electrode (Part No. 93-07) then inserted into the filtrate. As previous investigations (i.e., recovery studies) indicated no significant interferences from such competing anions as SO_4^{-2}, the use of nitrate interference suppressor solution was judged unnecessary. The pertinent QA/QC samples were treated in the same manner as for the unknowns.

2.4.1.10 Extractable Sulfate Ion and Exchangeable Potassium

The 20 gm soil: 50 ml freshly prepared 1N ammonium acetate (pH=5.5) suspensions were shaken in 125 mL Erlenmeyer flasks for 30 minutes. The suspensions then were filtered through sulfate-free Whatman No. 41 paper. A 10.0 ml aliquot of each filtrate was analyzed for sulfate ion using that turbidimetric method described in Attachment III.

FIGURE 2-1
ANALYTICAL SCHEME FOR THE SOLUBLE ARSENIC AND PHOSPHORUS DETERMINATIONS


1:1 pH
pH <7 (Bray)
Place 5.00 gm.-2mm mesh soil in 125 ml. Erlenmeyer flask, add 35 mL extractant solution (0.03N NH_4F and 0.025 N HCl), then shake for 1 hr.
Filter through Whatman No. 42 paper, repeating possibly a second time to ensure a clear filtrate. Record filtrate volume to nearest 1.0 mL.
~20 mL placed in labeled vial, for As determination by HG/AAS, as described on pp. 3-16, 3-17 in the MultiTech Laboratory SOP Manual.
2 mL aliquot prepared for phosphorus determination, as described on pp. 3-13, 3-14 in the MultiTech Laboratory SOP Manual.
pH ≥ 7 (Olsen)
Place 5.00 gm.-2 mm mesh soil in 125 mL Erlenmeyer flask, add 50 mL. extractant solution (0.5M $NaHCO_3$, pH 8.5), then shake for 1 hr.
Filter through Whatman No. 42 paper, repeating possibly a second time to ensure a clear filtrate. Record filtrate volume to nearest 1.0 mL.
~20 mL placed in labeled vial, then acidified to pH≈2 with concentrated H_2SO_4, for As determination by HG/AAS as described on pp. 3-16, 3-17 in the MultiTech Laboratory SOP Manual.
2 to 5 mL of filtrate prepared for phosphorus determination, as described on pp. 3-13, 3-14 in the MultiTech Laboratory SOP Manual.

The remainder of the filtrate was used for potassium determination using flame AAS. The pertinent QA/QC samples were treated in the same manner as for the unknowns.

The potassium nutrient status was estimated via subtracting the water soluble (saturation extract) K values from the exchangeable K values (Knudsen et al. 1982). To correct for probable K_e fixation--as a result of using air-dried, not field fresh, samples --the NH_4OAc solution was acidified rather than using the conventional pH 7.0 solution.

2.4.1.11 Total Sulfur

One gram samples, weighed to the nearest 0.1 mg, were mixed uniformly with an excess (~4gms.) of Eschka's mixture and heated to 800°C in a muffle furnace. The resulting sulfate then was dissolved in water, filtered and finally quantified using turbidimetric procedures. The pertinent QA/QC samples were treated in the same manner as for the unknowns. Details are presented in Attachment III.

2.4.2 Vegetation

2.4.2.1 Trace Element Analyses

Subsamples were withdrawn from the storage vials and wet ashed using a nitric acid/perchloric acid/hydrogen peroxide system, described in Attachment IV. The field blank, two different NBS SRMs

(i.e., orchard leaves and citrus leaves) and other pertinent laboratory-generated QA/QC samples were also digested using this procedure.

The digests, once diluted to standard (50 mL) volume, were analyzed for total concentrations of arsenic (As), cadmium (Cd), copper (Cu), iron (Fe), manganese (Mn), lead (Pb), and zinc (Zn) using ICP or AAS spectrophotometric procedures. Samples were "screened" initially using the ICAPES; the AAS subsequently was used to analyze arsenic concentrations present below the ICAPES' working detection limit. The element-specific methodologies followed closely those described in the USEPA's (1983) Manual for Water and Wastewater. Occasionally, the methods were modified slightly to accommodate intersample matrix variability. Such modifications are documented in the raw data report forms on file at MultiTech; these reports were prepared in a manner similar to those required for USEPA contract laboratories.

The QA/QC samples generated by the analytical laboratory either met or exceeded program requirements (MultiTech and Stiller and Associates 1985).

2.4.2.2 Crude Protein Estimates

A Labconco® brand micro-Kjeldahl distillation unit was used to determine percent Kjeldahl nitrogen. Technical details for its operation--following closely the manufacturer's suggested methodology--

are described in Attachment IV. The appropriate QA/QC samples were also analyzed, including NBS SRM 1571 (orchard leaves), by this same procedure.

The percent nitrogen data can be converted to percent (w/w) crude protein by dividing (the former values) by 6.25. This conversion factor assumes that plant proteins on average contain about 16% N (Allen 1974).

2.4.2.3 Total Phosphorus Analyses

Total-P was determined using essentially a two-step procedure. Initially, dried, ground, plant materials were wet ashed using a combination of concentrated nitric, perchloric, and sulfuric acids. The digestates were filtered, the filtrates diluted to standard volume, and aliquots withdrawn for phosphorus analysis by ICP. Technical details are described in Attachment IV. The appropriate QA/QC samples, including NBS orchard and citrus leaves, were also analyzed by this procedure.

2.4.2.4 Total Sulfur Analyses

Total sulfur was determined in the same manner as for soils, as described in Subsection 2.4.1.11 and Attachment III. The pertinent QA/QC samples, including NBS citrus leaves, were treated in the same manner as for the unknowns.

2.5 DATA ANALYSIS

2.5.1 Quality Assurance/Quality Control Considerations

The parameter-specific QA data sets were inspected to ensure that the associated raw data were of acceptable quality. These evaluations utilized the following statistical variables: known sample agreement (KSA), spiked sample recovery (SSR) and replicate sample agreement (RSA). Definitions for these variables, as well as QA data for soils and vegetation, are presented in Attachment V. These data were used to prepare the following statistical summaries for soils:

- Instrumental QAs (i.e., KSAs, SSRs, RSAs) averaged 98 ± 8% (n = 286);
- Sample Bank QAs (as above) averaged 100 ± 19% (n=186); and
- Field Duplicate and Colocated Sample QAs averaged 109 ± 24% (n = 129).

Similarly, these same summaries for plant materials are given below:

- Instrumental QAs averaged 100 ± 5% (n = 73);
- Sample Bank QAs averaged 94 ± 20% (n = 43); and
- Field Duplicate Sample QAs averaged 106 ± 30 (n = 9).

These summaries document two important QA considerations: first, instrumental and sample bank QA/AC goals were attained for both soils and plant materials; secondly, the variability intrinsic in

these materials resulted in exceeding the duplicate sample agreement (DSA) goal of 100 ± 20%, despite careful efforts to collect representative samples.

Attachment V indicates that colocated samples S328 and S329 are responsible for much of the soil sampling error. These 0-4 in. grab samples were collected within 40 feet from the A13 soil pit and 25 feet from each other. The DSA values for such parameters as EC, alkali/alkaline earth metals, plus soluble (SO_4^{-2}) sulfur and total sulfur levels exceeded 130%. This potential variability was accounted for during data evaluation.

Table 2-4 summarizes the QA/QC data for heavy metals analyses of Silver Bow Creek soils and vegetation. Three observations can be made from Part A of this table:

- The ICP and AAS systems utilized were functioning well within the set (generally 100 ± 15%) QA/QC bounds;
- Halvorson-extract arsenic KSAs exceed the set bounds, but are within the USEPA 95% confidence limits for arsenic in municipal sludge, while iron and manganese KSAs indicate low recoveries (possibly due to incomplete dissolution of the sample matrix, as HF was not used). Spiked sample recoveries were done only for arsenic and zinc, with particularly low results observed (and are probably due to inadequate concentration of analyte in the spike). However, overall analytical precision (as measured by RSA) was good; and

TABLE 2-4
QA/QC SUMMARIES FOR SOIL AND PLANT
HEAVY METALS DATA[a]

PART A. ACID EXTRACTABLE LEVELS IN SOILS

QA/QC Category	As	Cd	Cu	Fe	Mn	Pb	Zn
· Instrumental							
KSA%	102 ± 9(5)	98 ± 3(7)	99 ± 3(7)	108 ± 4(7)	103 ± 3(7)	103 ± 4(7)	99 ± 5(7)
SSR%	94 ± 15(5)	93 ± 4(5)	96 ± 8(5)	100 ± 10(5)	94 ± 13(5)	91 ± 5(5)	92 ± 6(5)
RSA%	104 ± 4(5)	99 ± 2(5)	100 ± 2(5)	100 ± 2(5)	101 ± 2(5)	100 ± 3(5)	100 ± 2(5)
· Sample Bank							
KSA%	162 ± 27(3)	111(1)	85(1)	67(1)	54(1)	94(1)	78(1)
SSR%	40 ± 18(2)	N.D.[b]	N.D.[b]	N.D.[b]	N.D.[b]	N.D.[b]	77(1)
RSA%	97 ± 6(7)	104 ± 9(8)	99 ± 10(8)	96 ± 8(8)	99 ± 3(8)	96 ± 5(8)	98 ± 4(8)
· Field Duplicates							
DSA%	103 ± 8(5)	98 ± 24(4)	105 ± 6(5)	81 ± 11(5)	96 ± 8(5)	88 ± 14(5)	99 ± 9(5)

PART B. PLANT AVAILABLE LEVELS IN SOILS

QA/QC Category	As	Cd	Cu	Fe	Mn	Pb	Zn
· Instrumental							
KSA%	101 ± 4(6)	112 ± 4(5)	101 ± 1(5)	101 ± 2(5)	99 ± 3(5)	98 ± 3(5)	101 ± 2(5)
SSR%	94 ± 2(5)	79 ± 3(5)	90 ± 7(5)	87 ± 4(5)	86 ± 2(5)	79 ± 4(5)	80 ± 3(5)
RSA%	101 ± 3(5)	99 ± 2(5)	100 ± 1(5)	97 ± 4(5)	99 ± 2(5)	98 ± 2(5)	99 ± 2(5)
· Sample Bank							
KSA%	N/A[c]	N/A[c]	N/A[c]	N/A[c]	N/A[c]	N/A[c]	N/A[c]
SSR%	140 ± 50(2)	N.D.[b]	84(1)	N.D.[b]	N.D.[b]	N.D.[b]	N.D.[b]
RSA%	102 ± 7(6)	101 ± 2(7)	100 ± 2(7)	100 ± 5(7)	101 ± 4(7)	103 ± 3(7)	101 ± 1(7)
· Field Duplicates							
DSA%	100 ± 15(4)	117 ± 10(4)	111 ± 12(5)	124 ± 14(4)	124 ± 17(5)	79 ± 28(4)	121 ± 19(5)

TABLE 2-4
QA/QC SUMMARIES FOR SOIL AND PLANT
HEAVY METALS DATA[a] (Cont.)

PART C. ACID EXTRACTABLE LEVELS IN PLANT MATERIALS

QA/QC Category	As	Cd	Cu	Fe	Mn	Pb	Zn
· Instrumental							
KSA%	99 ± 3(3)	102 ± 1(4)	98 ± 2(4)	98 ± 2(4)	98 ± 2(4)	105 ± 2(4)	100 ± 2(4)
SSR%	100 ± 10(3)	97 ± 3(3)	101 ± 3(3)	98 ± 5(3)	97 ± 4(3)	98 ± 10(3)	102 ± 3(3)
RSA%	100 ± 4(3)	100 ± 12(3)	100 ± 3(3)	101 ± 2(3)	100 ± 2(3)	100 ± 2(2)	101 ± 1(3)
· Sample Bank							
KSA%	103 ± 3(3)	132 ± 18(3)	96 ± 1(3)	102 ± 13(2)	89 ± 4(3)	88 ± 8(3)	94 ± 3(3)
SSR%	N.D.[b]	N.D.[b]	91(1)	N.D.[b]	N.D.[b]	N.D.[b]	N.D.[b]
RSA%	N.D.[b]	N.D.[b]	103 ± 6(2)	122 ± 33(2)	102 ± 5(2)	N.D.[b]	100 ± 1(2)
· Field Duplicates							
DSA%	82(1)	N.D.[b]	143(1)	90(1)	93(1)	171(1)	101(1)

(a) Presents arithmetic means and standard deviations for each parameter (e.g., Instrumental KSA) calculated, with sample size (n) given in parentheses following each set of statistics.
(b) N.D. = not determined (see discussion in text for details).
(c) N/A = not applicable (see discussion in text for details).

- The DSAs for cadmium, iron, and lead exceeded slightly the goal of 100 ± 20%. No particular sample pair can be isolated to explain these results. However, the effect of natural variability in heavy metals content on the average DSA may be magnified as a result of the relatively small sample size examined.

Regarding plant-available QA data (Table 2-4, part B), the instrumental systems utilized were working well within the set bounds of quality control. Several USEPA municipal sludge samples were subjected to the extraction procedure; however, as the certified levvels were for total metals content, no KSAs could be calculated. Spiked sample recoveries were performed only for arsenic and copper, with particularly high results observed for arsenic. Overall analytical precision was good. Duplicate sample agreement values exceeded the stated goal for all elements but arsenic. A major factor contributing to this exception is the results for the co-located pair S328-329, where all measured heavy metals but arsenic were well outside of the 80-120% QC bounds. The DSA heavy metal values for this pair ranged from 46% for lead to 151% for zinc.

The plant heavy metals QA data (Table 2-4, Part C) also demonstrate well-functioning ICP and AAS instrumentation. The sample bank KSA values are in control, except for cadmium. Sample digestates were analyzed for cadmium by ICP and by graphite furnace AAS, with essentially the same results. The cadmium KSAs are partly explained by the difficulty in accurate determination of the small ($\leq$0.11µg/g)

concentrations present in the standard reference materials. Only one SSR (for copper) was performed, with satisfactory results. The large RSA for iron is probably not due to contamination incurred in either the grinding or digestion processes; one possibility is incomplete washing of the material while in the field, although this also seems unlikely. The DSAs for copper and lead exceed the upper bound of the QA goal's range; no DSA was calculated for cadmium as one of the values was below the ICP detection limit. Two separate sets of plants were sampled at site A6. It is hypothesized that differences existed in soil (plant available) copper and lead levels, thus resulting in one set of plant materials being relatively contaminated.

When corrective action was judged necessary, the "out-of-control" samples were reprocessed. Such actions ranged from instrumental reanalysis of a digestate, to complete reanalysis of a particular, solid, sample. The validated data were then organized either by sample ("upgradient-downgradient") pair or by landowner site, as applicable. Arithmetic-based descriptive statistics were prepared for the duplicate sample results. Plant available heavy metal (soils) data were converted to common logarithms prior to calculation of various correlation coefficients.

2.5.2 Soils

The validated data for each soil parameter were compared against the "expected range" and "elevated condition" values presented in

Section VI.1 of Attachment VI. The heavy metal parameters were given particular attention, as discussed below.

A two-part process was used to evaluate whether particular total heavy metal levels exceeded the expected geochemical background levels, through data obtained during a literature search: first, the probable geologic parent material for each site was determined, and then the probable range in element-specific concentration for uncontaminated soils formed on the particular rock type was determined (Pendias and Pendias 1984).

Those laboratory values which exceeded the upper bound of the pertinent "background" value and which fell within the range observed at sites contaminated by nonferrous metal mining and/or processing were flagged by single asterisks (see Section 3.0). Strong acid extractable arsenic values were not judged as being elevated unless they were at least 150% of the upper bound for the geochemical background value. This was done in response to the consistently high sample bank KSA results discussed previously (Table 2-4, Part A). Similarly, given the low sample bank KSAs for iron and manganese, the sample specific results were doubled to evaluate the possibility of elevated levels for these metals. Preliminary assessments of phytotoxicity resulting from the elevated heavy metal levels were performed using those criteria developed, through literature review by Dr. Douglas Dollhopf et al. (1986). These assessments should be evaluated in conjunction with limitations explained in Attachment VI.

However, the presence of geochemically elevated levels of a given element does not translate necessarily into a serious environmental concern. For example, many interacting soil factors affect heavy metal availability (Harmsen 1977), while the "soil-plant barrier" can in some cases, mitigate transport into the food chain (Adriano 1985). Thus, plant-available data also were generated to assess the potential for phytotoxicity and possibly bioaccumulation effects.

A two-phased approach was used to evaluate the plant available information. First, those levels which may adversely affect crop production or revegetation efforts were flagged with double asterisks (see Section 3.0). This effort utilized Table 4.5-7 in the Work Plan, a coal mine reclamation paper by Schafer (1979), and the criteria developed by Dollopf et al. (1986). Secondly, the probable chemical speciation of each heavy metal may be assessed by reference to the qualitative pH-Eh stability diagrams shown in Attachment VII.

The reclamation- and agricultural-related parameter results were evaluated by reference to guidelines contained in Schafer (1979) and those prepared by the Cooperative Extension Service (Montana State University Various Dates). The values utilized are shown in Attachment VI.

2.5.3 Plant Materials

The heavy metals data were evaluated in a manner similar to that used for assessing the acid extractable soils data. Key evaluation criteria are presented in Attachment VI; Pendias and Pendias (1984) was consulted occasionally as well. Those laboratory values which exceeded the upper bound of the pertinent "background" value and which fell within the range observed at sites contaminated by nonferrous metal mining and/or processing were flagged by single asterisks (see Section 3.0). Cadmium values were not judged to be elevated unless they were at least 115% of the upper bound for the biogeochemical background value. This was done in response to the consistently high sample bank KSA result discussed previously (Table 2-4, Part C). Once the elevated levels were identified, they were screened for potential toxicity to livestock via reference to Part B of Table 4.5-10 in the Work Plan (MultiTech and Stiller and Associates 1984a) and to the toxicity criteria developed by Dollhopf et al. (1986). Heavy metal concentrations which probably constitute a threat to livestock consuming them were then denoted using two asterisks. (see Section 3.0 Tables).

The principal reference used for evaluating macronutrient (nitrogen, phosphorus, sulfur) data was that edited by Chapman (1973). The assessments for grass species also utilized the report by Hamilton and Lang (1961). Supplemental references for alfalfa included those by Rominger et al. (1975), plus Pumphrey and Moore (1965).

DRAFT

3.0 DATA INTERPRETATION

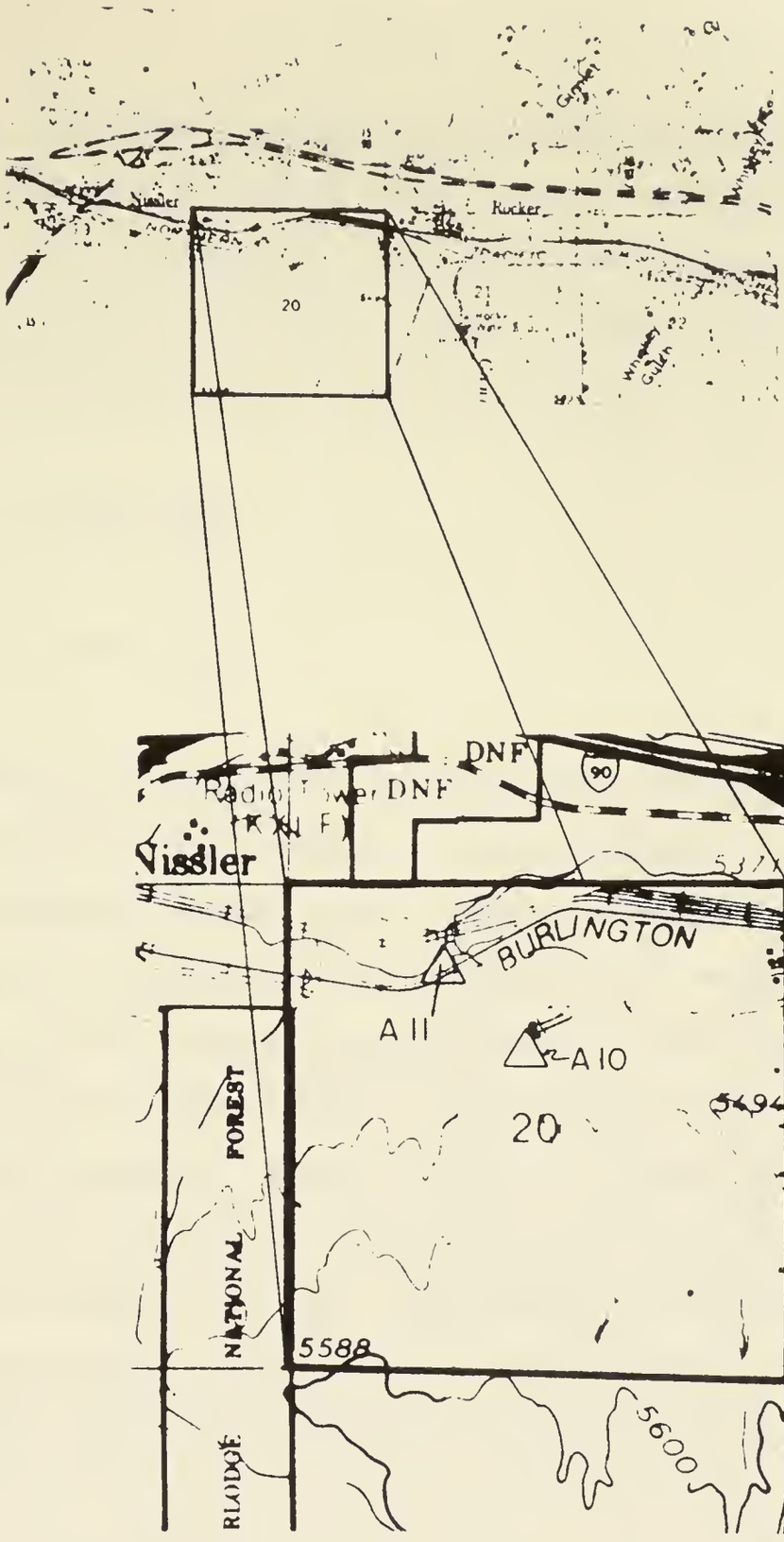
This section presents the field and laboratory data gathered at each of the six Phase One sampling sites. The site discussions are ordered in a "downstream" direction; thus, Thurmond's sites are discussed first, while Dutton's site is discussed last (see Map 2-1). Each site discussion includes (1) a brief site description/ site map; (2) tabulated analytical data for soils plus narrative; and (3) tabulated analytical data for vegetation, plus narrative. Site-specific technical details are presented in Attachment VIII.

3.1 THURMOND'S SITES

The Thurmond sites, A10 and A11, were both in pastureland: A10 is upgradient (uphill) from A11. The two sites are shown on Map 3-1.

Site A10 is midway on a moderately sloping, north-facing alluvial fan. Erosion is moderate. The site's perennial vegetation (clover, bluegrass, and bromegrass) is irrigated from a well and is used for livestock forage. The soil texture is coarse-loamy. It probably is derived from alluvial and lake deposits, including volcanic ash and mudflow materials.

Site A11 is about 30 ft from Silver Bow Creek, on a gently sloping, northwest-facing alluvial fan. Erosion is moderate. The site's perennial vegetation is irrigated by water pumped from Silver Bow Creek. A11's soil texture also is coarse-loamy. The soil sample



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SOURCE: USGS 15'

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SOURCE:
USGS/USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-1
SAMPLING SITES AT THURMOND'S

was taken from a horizon which contained a mixture of mill tailings and alluvial materials. The horizon overlays flood-reworked sediments that include silt lenses, gravelly sand, and pockets of what appear to be railroad ballast. At the time of sampling (see Table 2-3), depth to water table was 17 in.

3.1.1 Soils Data

3.1.1.1 Site A10

Laboratory results for Site A10 are shown in Part A of Table 3-1. No salinity and only low sodium hazards are evident within the paraneutral, sandy loam horizon sampled. Macronutrient levels range from adequate (for nitrogen) to very low (for phosphorus), but are not necessarily deficient. Acid digestable ("total") and extractable ("plant-available") heavy metal levels are generally within expected ranges. The two possible exceptions are total arsenic and cadmium, as both exceed the expected upper bounds of 25 µg/g and 1.61 µg/g., respectively, for soils formed on volcanic rocks (Pendias and Pendias 1984). Total sulfur and extractable sulfate levels are within the expected ranges.

3.1.1.2 Site A11

Laboratory results for this site are shown in Part B of Table 3-1. No salinity and only low sodium hazards are evident within the paraneutral, sandy loam horizon sampled. Macronutrient levels range

TABLE 3-1
DATA SUMMARY FOR THURMOND'S SITES (abc)

PART A. UPGRADIENT SITE, A10.

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-5	51.4	4.06	2.25	0.226	106	0.872	10,600	0.156	555	6.96	52.5	0.390	89.5	2.44

Soil Depth (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-5	6.62	1.729	95.2	7.83	11.4	380	77.6	17.3	86.6	35.02	0.94	59.4	27.4	13.2	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• POPR	<0.365	<0.2	6.25	45.6	33.8	<4.5	29.0	3.42	0.147	0.2218

PART B. DOWNGRADIENT SITE, A11.

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-9	2560**	95.9**	74.0*	2.44*	2060*	402*	19,100	0.656	716	8.64	667*	0.624	6420**	514**

	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
	6.90	1.337	5.6	22.7	202	5650	155.9	33.8	0.00	76.32	1.44	69.2	26.0	4.8	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• CAREX sp.	2.765	<0.2	16.9	479*	92.5	4.95	150*	2.57	0.134	0.2917

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40+1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N, P, total S, and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105+ 1°C) basis.
(b) Plant heavy metals data are given as mg/kg, "air-dried" (40+ 1°C) basis; N,P and S are as % w/w, "air-dried" basis.
(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

from very low (if not deficient for exchangeable potassium, K_e) to low. Total levels of arsenic, cadmium, copper, lead, and zinc clearly exceed their respective geochemical background levels (see Attachment VI). With the exception of lead, the plant-available levels of these same elements also exceed their respective background concentrations. The cumulative concentration of extractable heavy metals (particularly arsenic, copper, and zinc) appears to be at a phytotoxic (plant killing) level, despite the presence of nearly 100% vegetative cover. Possibly,the seedlings of those plant species present are tolerant to heavy metals, and metal concentrations decrease rapidly (to generally nonphytotoxic levels) within the unsampled portion of the rooting zone. Total and extractable sulfur levels are very slightly and definitely elevated, respectively. Given the elevated metals levels, such elevated sulfate ion levels could arise from weathering of pyritic minerals contained in the mill tailings.

3.1.2 Plant Data

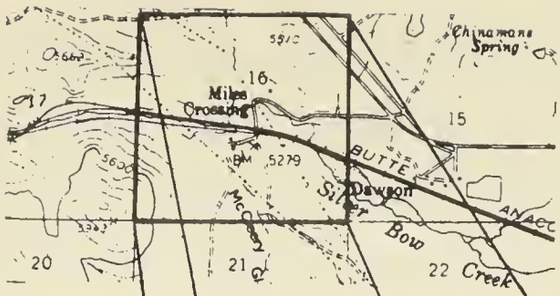
All of the heavy metal results at site A10 are within their respective biogeochemical background levels. The same can be said of the nitrogen, phosphorus, and sulfur levels (Chapman 1973); however, nitrogen is on the upper end, while phosphorus is on the lower end, of the expected range. Furthermore, the nitrogen:sulfur ratio indicates a possible borderline deficiency in sulfur, even though plant values are moderate.

At Site A11, iron is clearly elevated while zinc is slightly elevated. The remaining elements are present within their respective biological and geochemical background levels; however, arsenic concentration is probably at the upper bound of the expected range. None of these elevated elements are present at levels toxic to cattle (MultiTech Work Plan 1985; Dollhopf et al. 1986). The levels of nitrogen, phosphorus and sulfur appear to be within their respective backgrounds. More specifically, nitrogen is moderate to low, phosphorus is low, and sulfur is at the high end of the background range.

3.2 KONDA'S SITES

Three sites, identified as A1 through A3, were sampled within Konda's field. These sites represent a contamination gradient, from the relatively clean A1 upland site to the apparently contaminated A3 flood-channel site. Site A1 is above the inactive Miles Ditch, and Site A2 is below it. All three sites are shown in Map 3-2, and contain fine-loamy soils.

Site A1 is located on a gently sloping, south-southwest facing footslope of an alluvial fan. It is adjacent to foothills and outcrops of volcanic origin. The well-drained site exhibits medium permeability and is slightly eroded. The vegetation is representative of shallow, saline rangeland sites, which also were observed in the Deer Lodge Valley (Ross and Hunter 1976). The predominant uses of these subirrigated lands is forage production and livestock grazing.



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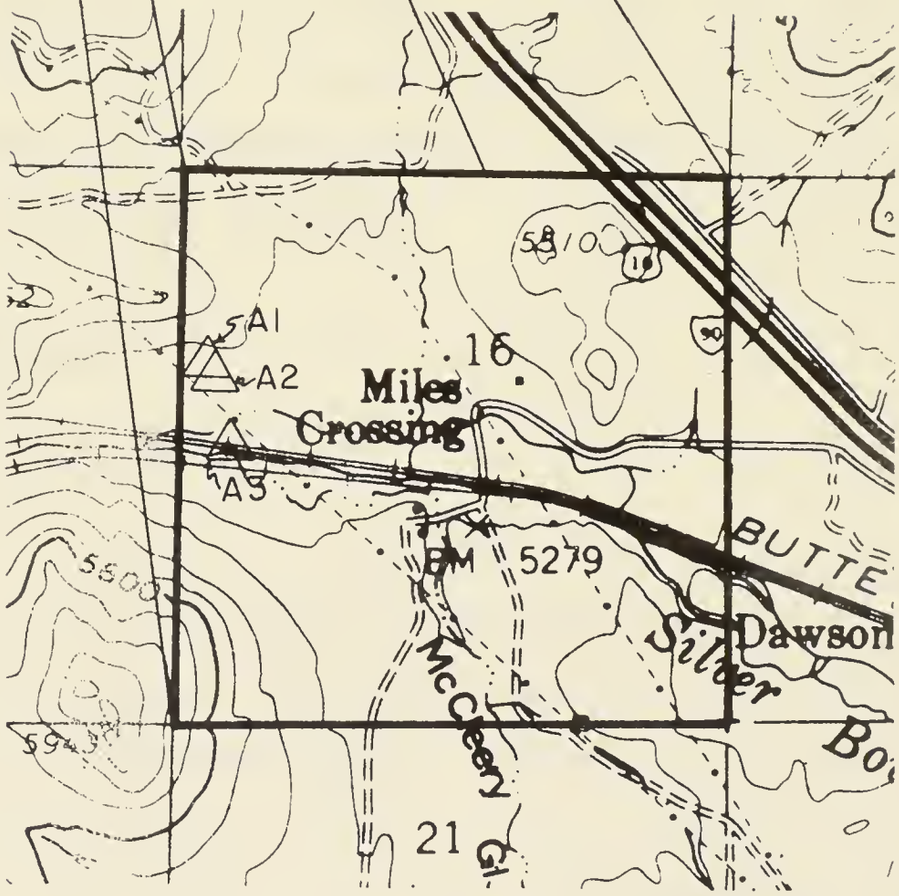
SOURCE: USGS 15'



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SOURCE:
USGS/USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-2
SAMPLING SITES AT KONDA'S

Site A2 is located on a level, south-southwest facing slope of an alluvial fan. Site drainage is moderate, permeability is medium, and present erosion is slight. Sedge and rush predominance indicates a wetland/subirrigated range site (Ross and Hunter 1976). Hay is harvested for livestock from this land.

Site A3 is located on level ground within an historic flood-channel. Site drainage is poor to moderate, premeability is medium, and erosion is moderate. Salt seeps are common, and vegetative cover was about 50%. Sandy, rust-colored mill tailings were observed scattered throughout the soil between 15 and 30 in. deep. The water table was encountered at 43 in.

3.2.1 Soils Data

3.2.1.1 Site A1

Laboratory results for Site A1 are shown in Part A of Table 3-2. Soil reaction changes from moderately alkaline to very strongly alkaline with increasing depth. The electrical conductivity (EC) values within the upper 22 in. of soil indicate a high salinity hazard; the soil profile is also sodium-affected. Exchangeable potassium (K_e) is adequate within the rooting zone, while nitrogen and phosphorus levels are moderate to high (implying recent fertilizer addition). Total and plant-available heavy metal levels are generally within their expected ranges, with the possible exceptions of total and plant-available arsenic and total cadmium.

TABLE 3-2
DATA SUMMARY FOR KONDA'S SITES.(abc)

PART A. UPPERMOST SITE, A1.

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-12	50.5	7.61	2.00	0.322	51.5	7.60	7250	7.24	380	5.28	18.6	2.10	62.0	12.2
12-22	6.75	1.63	0.550	0.052	28.2	1.42	7450	1.48	293	2.88	11.5	0.414	56.0	0.782
22-28	<5.76	<0.72	<0.490	0.024	22.0	0.858	11,400	0.806	248	2.40	15.7	0.422	47.5	0.452

Soil Depth (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-12	7.95	14.53	19.4	24.6	6750	2210	424.9	362.8	66.3	3257.32	28.04	61.3	33.6	5.1	Sandy Loam
12-22	9.14	11.03	24.6	12.2	1330	1050	40.3	55.8	160.3	2357.32	56.44	64.1	31.7	4.2	Sandy Loam
22-28	9.50	4.66	31.2	8.73	45.1	590	8.6	6.3	230.5	874.32	55.28	69.2	25.1	5.7	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• AGSP	0.853	<0.2	33.6	64.5	20.8	112*	21.4	2.83	0.235	0.1183

PART B. TOPOGRAPHICALLY INTERMEDIATE SITE, A2.

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-6	80.0*	9.65*	5.99*	1.39*	420*	128*	10,600	13.1	936	13.5	387*	62.0*	624**	37.8

Soil Depth (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-6	7.98	3.19	53.0	21.9	24.7	1120	134.9	97.8	506.3	342.32	5.48	31.3	53.0	15.7	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• CAREX sp.	2.487	0.2	9.30	114	63.5	4.60	35.0	2.73	0.145	0.3145

TABLE 3-2
DATA SUMMARY FOR KONDA'S SITES.(abc) (Cont.)

PART C. LOWERMOST SITE, A3.

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-15	652**	8.62*	27.8*	1.68*	3140*	362*	21,200	17.0	5650*	7.36	950*	29.2*	4600**	109**
15-30	187**	12.7*	10.1*	2.32*	1200*	22.8	11,100	16.5	1850*	5.04	471*	28.6*	1850**	162**
30-46	<5.76	<0.51	0.588	0.038	36.8	0.056	13,000	1.38	264	55.8	30.1	1.40	246*	13.1

Soil Depth (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-15	7.33	3.65	28.0	10.2	886	3780	441.9	64.8	100.8	576.32	6.78	48.3	39.2	12.5	Loam
15-30	7.23	3.78	18.8	9.81	1390	2450	482.9	32.4	116.3	484.32	5.76	45.3	46.6	8.1	Loam/Loamy Sand
30-46	6.94	3.86	44.8	3.21	1150	2630	500.9	61.8	119.2	449.32	5.04	41.6	46.3	12.1	Loam/Silt Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• ELCI	20.04*	0.7**	124*	222	264	65.0**	182*	3.17	0.196	0.4207
• CAREX sp.	6.635*	0.8**	22.6	77.0	115	5.30	194*	1.89	0.166	0.1554

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40+1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N,P,total S, and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105+ 1°C) basis.

(b) Plant heavy metals data are given as mg/kg, "air-dried" (40+ 1°C) basis; N,P and S are as % w/w, "air dried" basis.

(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

The rationale for this assessment is the same offered for Site A10. Total and extractable (SO_4^{-2}) sulfur levels are clearly elevated within the uppermost 12 in. and uppermost 22 in. respectively. Soil salinity and alkalinity may result from salts evaporated from shallow ground water as it travels by capillary action to the surface. These salt accumulations may include relatively high levels of sodium sulfate (Na_2SO_4) and possibly dibasic calcium arsenate ($CaHAsO_4$).

Plant-available correlations were calculated, using the logarithm of the heavy metal concentration (log [HM]) as the dependent variable, and depth, pH, and log [HM]s as the independent variables. The results are shown in Table 3-3, Part A, which lead to three major observations:

- Non-significant ($p>0.10$) inverse associations occur between plant-available levels and soil depth;

- With the exception of lead, significant ($p<0.10$) to highly significant ($p\leq 0.05$) inverse associations occur between plant-available levels and soil pH; and

- Copper, iron, and manganese are tied for the greatest number of highly significant positive associations with the other elements, while lead exhibited non-significant associations with all of the other elements.

TABLE 3-3
PLANT AVAILABLE CORRELATIONS SUMMARY FOR TWO OF THE KONDA SITES.(a)

PART A. UPPERMOST SITE, A1.

Independent Variables		Dependent Variables (log[HM]s) As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		-0.9844	-0.9738	-0.9550	-0.9684	-0.9551	-0.8608	-0.9331
r^2		0.9690	0.9483	0.9120	0.9378	0.9122	0.7410	0.8707
• pH								
r		-0.9924*	-0.9975**	-0.9999**	-0.9989**	-0.9999**	-0.9727	-0.9977**
r^2		0.9848	0.9950	0.9998	0.9978	0.9998	0.9461	0.9954
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9986**	0.9922*	0.9972**	0.9923*	0.9369	0.9818
	Cd	0.9818	--	0.9974**	0.9997**	0.9974**	0.9540	0.9904*
	Cu	0.9922*	0.9974**	--	0.9988**	1.0000**	0.9730	0.9978**
	Fe	0.9972**	0.9997**	0.9988**	--	0.9988**	0.9606	0.9933*
	Mn	0.9923*	0.9974**	1.0000**	0.9988**	--	0.9730	0.9978**
	Pb	0.9369	0.9540	0.9730	0.9606	0.9730	--	0.9862
	Zn	0.9818	0.9904*	0.9978**	0.9933*	0.9978**	0.9862	--

TABLE 3-3
PLANT AVAILABLE CORRELATIONS SUMMARY FOR TWO OF THE THREE KONDA SITES (Cont.)(a)

PART B. LOWERMOST SITE, A3.

Independent Variables		Dependent Variables (log[HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
	r	-0.8055	-0.8286	-0.9780	-0.8712	0.7835	-0.8690	-0.7834
	r^2	0.6488	0.6866	0.9565	0.7590	0.6139	0.7552	0.6137
• pH								
	r	0.9358	0.9492	0.9980**	0.9716	-0.9225	0.9705	0.9224
	r^2	0.8757	0.9010	0.9960	0.9440	0.8510	0.9419	0.8508
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9992**	0.9115	0.9927*	-0.9993**	0.9932*	0.9993**
	Cd	0.9992**	--	0.9272	0.9967*	-0.9971**	0.9971**	0.9971**
	Cu	0.9115	0.9272	--	0.9545	0.8959	0.9531	0.8959
	Fe	0.9927*	0.9967*	0.9545	--	0.9988**	0.9999**	0.9876
	Mn	-0.9993**	-0.9971**	-0.8959	0.9988**	--	0.9883*	0.9978**
	Pb	0.9932*	0.9971**	0.9531	0.9999**	0.9883*	--	0.9883*
	Zn	0.9993**	0.9971**	0.8959	0.9876	0.9978**	0.9883*	--

(a) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.988, df=1; two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$df=1).

3.2.1.2 Site A2

Laboratory results for the "A1" horizon sampled are presented in Table 3-2, Part B. The moderately alkaline silt loam exhibits slight salinity and moderate sodicity hazards. Exchangeable potassium (K_e) is very high, while nitrogen and phosphorus levels are both moderate to high. Total levels of arsenic, cadmium, copper, lead, and zinc exceed their respective upper bounds of geochemical background levels. With the exception of zinc, the same can be said for the plant-available levels. The absence of gross phytotoxicity (excepting zinc) may be due to the chelation potential of the horizons within the rooting zone, which are probably rich in organic matter. Total and soluble sulfur levels are present within their expected background levels.

3.2.1.3 Site A3

Laboratory results for Site A3 are shown in Part C of Table 3-2. Soil reaction is paraneutral throughout the generally loamy profile. The salinity hazard is slight, while the sodium hazard is moderate. Macronutrient levels range from high for nitrogen to low for both phosphorus and potassium. The total levels of arsenic, cadmium, copper, manganese, lead, and zinc exceed their respective geochemical background levels, as measured within the upper 30 in. of the soil profile. With the exceptions of copper and manganese, the same can be said for the plant-available heavy metal levels. The cumulative plant-available metals concentration is probably phytotoxic

to seedlings, and consequently the condition of the vegetation is poor. Total and soluble (SO_4^{-2}) sulfur levels are elevated throughout the profile, possibly due to the presence of partially weathered pyritic minerals contained within the mill tailings.

Plant-available correlations, prepared as discussed for Site A1, are shown in Part B of Table 3-3. Three major observations from the table are as follows:

- Non-significant associations occur between plant-available levels and soil depth;

- Only copper exhibited a highly significant positive association with pH; and

- Cadmium and manganese are equal in the greatest number of highly significant associations, while copper exhibited non-significant associations with all of the other elements.

3.2.2 Plant Data

With the exception of lead, the remaining heavy metals levels at Site A1 are within their expected biogeochemical backgrounds. The lead contamination is puzzling, given the probable absence of motor vehicle exhaust and the relatively low plant-available levels; the QA/QC data in Attachment V indicate no error in either the digestion or instrumental (quantitation) steps. The levels of nitrogen,

phosphorus, and sulfur are within their respective background ranges. Nitrogen and phosphorus levels are moderate, while the sulfur level is moderate-to-low. The nitrogen:sulfur ratio of ~24 indicates a probable sulfur deficiency, despite the high soil sulphate levels within the rooting zone.

With the possible exception of arsenic, the heavy metals levels at Site A2 are within their expected biogeochemical backgrounds; arsenic appears to be at the upper bound of the expected range. The nitrogen, phosphorus, and sulfur levels are within their respective background ranges. The respective ratings for these macronutrients are moderate, low, and moderate to high.

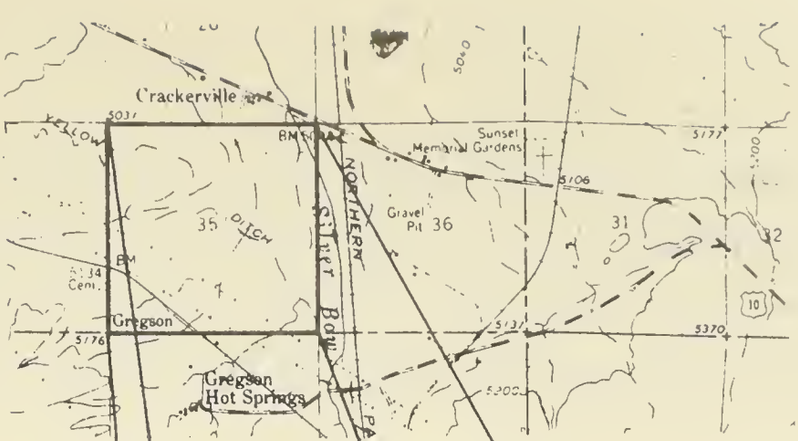
At Site A3, arsenic, cadmium and zinc levels are elevated in both genera sampled (Basin wildrye and sedge), while copper and lead are elevated in Basin wildrye. The copper could be toxic to cattle and/or sheep, while arsenic in the wildrye could be toxic to sheep. The lead and cadmium levels probably constitute a problem to livestock, particularly if they graze solely on such feedstuffs. Nitrogen levels appear to be moderate for wildrye and low for the sedge (Carex) species. The levels of phosphorus are at the lower bounds of their respective background ranges for both species. Sulfur concentrations are elevated in wildrye, but moderate for sedge.

3.3 PETERSON'S SITES

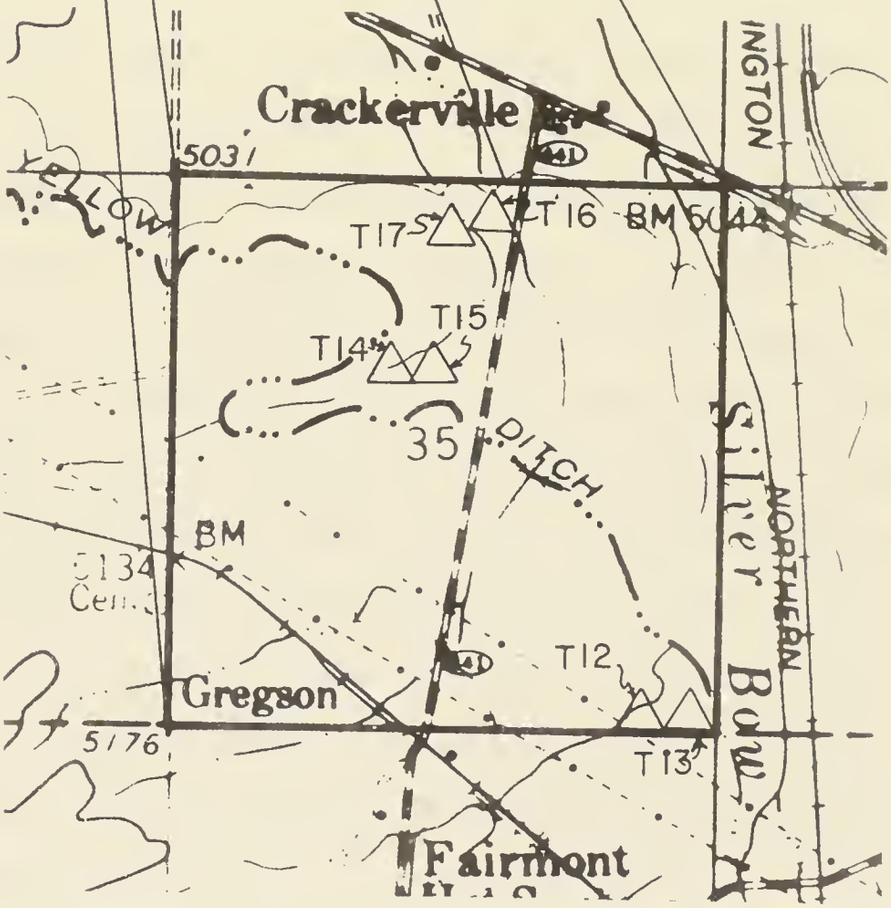
Peterson's ranch was sampled in six sites, arranged in three upgradient:downgradient pairs: T12:T13, T14:T15, and T17:T16. These site pairs are shown on Map 3-3. Sites T12:T13 and T14:T15 were on gently sloping north- or northeast-facing slopes, while T14 faced southeast and T15 faced northwest. Both T12 and T13 are on an alluvial terrace, while sites T14, T15, T16, and T17 are on an alluvial fan.

Site T12 has poor to moderate drainage, with slow permeability; no erosion is evident. At Site T13, the drainage is poor, with medium permeability and severe erosion. The predominance of sedge and rush species at site T12 indicates wetland/subirrigated range; land use is for pasture. Vegetative cover is less than 5% on Site T13, with scattered stands of sedge and rush on slightly elevated ground. Sites T12 and T13 have clayey-over-sandy soils, probably derived from Quaternary alluvium.

Site T14 is well drained, permeability is medium to rapid, and the erosion condition is severe. At Site T15, the drainage is poor to moderate, permeability is slow to medium, and the present erosion condition is moderate. Land use at Site T14 is irrigated alfalfa hay; at site T15, irrigated oats. Alfalfa production appeared poor, and the plants growing along the margin of the swale where soils were sampled had yellow-tipped leaves with green veins. This coloration is symptomatic of zinc-induced copper deficiency. Soils at both Sites T14 and T15 are fine-loamy.



SOURCE: USGS 15'



SOURCE:
USGS/USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-3
SAMPLING SITES AT PETERSON'S

Soil at Sites T17 and T16 also are fine-loamy. Irrigated alfalfa was produced on both sites. The first-year alfalfa planted at Site T16 either died or did not nodulate; scattered stands of hoary cress and field bindweed occurred within the generally denuded site.

3.3.1 Soils Data

3.3.1.1 T12:T13 Pair

The laboratory data for Sites T12:T13 are presented in Part A of Table 3-4. Site T12 (uphill) soils are non-saline, slightly acidic to paraneutral (with increasing depth), loams to sandy loams. Sodicity hazard is rated as moderate to slight, with increasing depth. With the exception of surficial nitrogen (0-5 in.)--which is present at moderate levels--the macronutrient levels are very low to low. Total concentrations of cadmium, copper, lead, and zinc exceed the upper bounds of their respective geochemical background values. The plant-available cadmium level is slightly elevated, but probably does not pose a phytotoxic concern. Total and soluble (SO_4^{-2}) sulfur levels are generally within their expected (background) concentrations; however, soluble sulfur appears to be low at depth (>5 in.).

Site T13 (downhill) soils are moderately to slightly acidic, non-saline sands to sandy loams. Sodium hazard is rated as moderate. Macronutrient levels are moderate for nitrogen and low to very low for phosphorus and potassium. Total levels of cadmium, copper,

TABLE 3-4
DATA SUMMARY FOR PETERSON'S SITES[a,b,c]

PART A. T12 (UPGRADIENT) VS. T13 (DOWNGRADIENT) PAIR

Site No./Soil Depth (in)		As		Cd		Cu		Fe		Mn		Pb		Zn	
		T	P	T	P	T	P	T	P	T	P	T	P	T	P
T12,	0-5	37.2	4.60	5.35*	1.19*	444*	4.88	12,500	0.482	270	8.96	127*	5.66	347*	26.2
	5-17	<5.64	1.93	<0.50	0.026	17.7	<0.096	4200	0.116	65.5	0.860	<7.8	<0.19	33.0	0.566
T13,	0-3	17.6	1.51	10.8*	3.74*	745*	93.0*	7700	<0.056	1440*	52.6	50.0*	0.512	775**	286**
	3-10	9.3	1.22	4.85*	3.64*	318*	175*	4050	0.244	173	7.58	8.86	0.494	316*	112**
	10-18	19.7	3.52	3.37*	1.07*	207*	18.2	4400	0.286	520	9.8	78.2*	5.00	419*	102**

Site No./Soil Depth (in)		pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
T12,	0-5	6.19	0.86	64.0	7.99	133	1520	38.9	5.4	163.3	114.32	4.55	50.0	35.7	14.3	Loam/Sandy Loa
	5-17	6.67	0.64	2.6	<0.34	<5	280	12.1	5.5	32.7	62.22	3.73	64.2	26.3	9.5	Sandy Loam
T13,	0-3	5.59	1.53	19.6	1.08	21.3	300	77.9	15.8	99.9	185.32	5.01	59.7	30.3	10.0	Sandy Loam
	3-10	6.45	0.95	6.8	2.78	15.6	230	62.2	16.9	50.4	150.32	4.36	94.2	3.4	2.4	Sand
	10-18	5.99	1.82	43.0	2.79	102	330	89.0	17.2	70.5	264.32	6.72	70.2	20.9	8.9	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• T12, CAREX sp.	0.935	0.3	8.45	218	73.5	<4.5	67.5	1.39	0.165	0.1825
• T13, CAREX sp.	4.230	1.35**	80.5*	153	70.0	24.5	329*	1.38	0.098	0.4012

PART B. T14 (UPGRADIENT) VS. T15 (DOWNGRADIENT) PAIR

Site No./Soil Depth (in.)		As		Cd		Cu		Fe		Mn		Pb		Zn	
		T	P	T	P	T	P	T	P	T	P	T	P	T	P
T14,	0-4	214**	31.1*	6.55*	0.976	214*	21.0	15,000	0.734	500	80.8*	110*	5.04	158*	17.2
T15,	0-8	172**	14.8	6.45*	0.928	325*	79.2*	19,800	6.56	381	3.56	122*	15.0*	264*	23.6

TABLE 3-4
DATA SUMMARY FOR PETERSON'S SITES[a,b,c] (Cont.)

PART B. T14 VS. T15 (Cont.)

Site No./Soil Depth (in)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
T14, 0-4	4.03	4.46	117	94.1	81.1	330	370.9	63.8	0.0	279.32	3.53	68.7	23.8	7.5	Sandy Loam
T15, 0-8	7.72	1.21	96.0	19.7	6.25	650	114.9	46.1	372.6	71.02	1.42	40.0	42.1	17.9	Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• T14, MESA	2.193*	<0.2	41.7*	222	47.0	51.0**	60.0*	2.15	0.246	0.4228
• T15, AVSA	10.86*	0.4	14.2	222*	38.8	<4.5	63.0*	4.34	0.418	0.7237

PART C. T17 (UPGRADIENT) VS. T16 (DOWNGRADIENT) PAIR

Site No./Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
T17, 0-5	115**	3.39	7.18*	0.808	339*	10.1	37,700*	0.226	1010	3.14	168*	1.17	349*	13.7
T16, 0-4	249**	20.0*	8.20*	1.24*	391*	66.0*	19,800	0.840	835	79.6*	229*	13.4*	284*	31.2

	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
T17, 0-5	5.74	0.93	58.0	13.48	<5	330	65.6	24.4	96.4	51.92	1.39	37.4	30.3	32.3	Clay Loam
T16, 0-4	4.02	1.13	6.0	28.2	55.5	350	102.9	24.7	37.0	70.92	1.63	64.4	21.3	14.3	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• T17, MESA	0.951	0.6**	11.0	166	27.5	<4.5	50.5	3.17	0.289	0.2966
• T16, MESA	1.250	0.8**	12.0	157	29.0	<4.5	49.1	2.74	0.263	0.3346

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40+1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N, P, total S and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105+ 1°C) basis.

(b) Plant heavy metals data are given as mg/kg, "air-dried" (40+ 1°C) basis; N,P and S are as % w/w, "air Dried" basis.

(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

manganese, lead, and zinc exceed the upper bounds of their respective geochemical background values. With the exception of manganese and lead, the same is true for these metals' plant-available levels. The cumulative concentration of plant-available metals is hypothesized to be the cause of the denuded soils. Total and soluble sulfur concentrations are within their expected background levels.

Plant-available correlations were calculated for site T13, using log [HM]s as the dependent variable, while depth, pH, and log [HM]s constituted the independent variables. The results are presented in Table 3-5, which shows two important findings:

- Non-significant ($p>0.10$) associations occur between log [HM]s and both depth and pH; and

- Highly significant ($p\leq 0.05$) inverse associations occur between cadmium and lead plus iron and zinc, while a less significant ($p<0.10$) inverse association occurs between arsenic and copper.

3.3.1.2 T14:T15 Pair

The laboratory data for these sites are presented in Table 3-4, Part B. Site T14 soil is extremely acid (pH<4.5), moderately saline, and has a sandy loam texture; the sodium hazard rating is slight. Macronutrient levels range from moderate (for phosphorus and nitrogen)

TABLE 3-5
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE T13 SAMPLE AT PETERSON's SITE(a)

Independent Variables		Dependent Variables (log [HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
	r	0.7551	-0.8753	-0.6984	0.9068	-0.7985	0.8592	-0.9041
	r^2	0.5702	0.7662	0.4878	0.8223	0.6376	0.7382	0.8174
• pH								
	r	-0.2296	0.0213	0.3092	0.7947	-0.9041	-0.0537	-0.7985
	r^2	0.0527	0.0004	0.0956	0.6315	0.8174	0.0029	0.6376

		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	-0.9780	-0.9966*	0.4083	-0.2083	0.9842	-0.4025
	Cd	-0.9780	--	0.9574	-0.5899	0.4079	-0.9995**	0.5848
	Cu	-0.9966*	0.9574	--	-0.3316	0.1268	-0.9662	0.3256
	Fe	0.4083	-0.5899	-0.3316	--	-0.9779	0.5634	-0.9999**
	Mn	-0.2083	0.4079	0.1268	-0.9779	--	-0.3781	0.7207
	Pb	0.9842	-0.9995**	-0.9662	0.5834	-0.3781	--	-0.5582
	Zn	-0.4025	0.5848	0.3256	-0.9999**	0.7207	-0.5582	--

(a) One asterisk (*) signifies 90% confidence ($P_{0.10}$ 0.988, df=1); two asterisks(**) signifies $\geq$ 95% confidence ($P_{0.05}$ =0.997, df=1).

very low (for exchangeable potassium). Total levels of arsenic, cadmium, copper, lead, and zinc exceed the upper bounds of their respective geochemical background values; the arsenic level is probably phytotoxic (Dollhopf et al. 1986). Plant-available levels of arsenic and manganese also are elevated, with manganese present probably at phytotoxic concentrations. Total and soluble sulfur are within their expected levels.

The T15 soil is a mildly alkaline, non-saline and non-sodic loam. All macronutrient levels are moderate to high. Total heavy metal levels status is the same as for site T14, although copper, lead, and zinc concentrations are even greater. Plant-available concentrations of copper and lead are elevated, copper to potentially phytotoxic levels. Total and soluble sulfur are within their expected background levels.

3.3.1.3 T17:T16 Pair

The laboratory data for these sites are presented in Table 3-4, Part C. Site T17 is a moderately acidic, non-saline and non-sodic clay loam. Macronutrient levels are probably moderate for nitrogen, but low for potassium and very low for phosphorus. Excepting manganese, total metals levels exceed the upper bounds of their respective geochemical background values, while plant-available levels fall within their respective background values. However, total arsenic concentration represents probably phytotoxic conditions for this metalloid. This fine-textured soil exhibits relatively high

retention capacity of ions by clay minerals; this process would reduce heavy metal ion concentrations in the soil solution. The total sulfur level is within the expected range, while the sulfate level is low.

Site T16 is an extremely acid (pH<4.5), non-saline and non-sodic, sandy loam. Macronutrient levels are interpreted in the same manner as for T17. With the exception of iron and manganese, the total heavy metal levels exceed the upper bounds of their respective geochemical background values. Those elements exceeding the expected plant-available levels include arsenic, cadmium, copper, manganese, and lead. The presence of potentially phytotoxic levels of manganese--in the face of "normal" concentrations of total manganese--can be explained by the probable acidity of the soil solution. Total and soluble sulfur levels are within their respective background levels.

3.3.2 Plant Data

The heavy metal and nutrient results for the sedge species at T12 are generally within expected biogeochemical values. However, nitrogen and phosphorus are on the low end of their respective background values, while sulfur level is moderate. The sedge at T13 represents poor quality forage, but is generally nontoxic to livestock, with the one probable exception of cadmium. Nitrogen level in the T13 sedge is low, and possibly deficient; phosphorus is low-to-deficient, and sulfur is elevated.

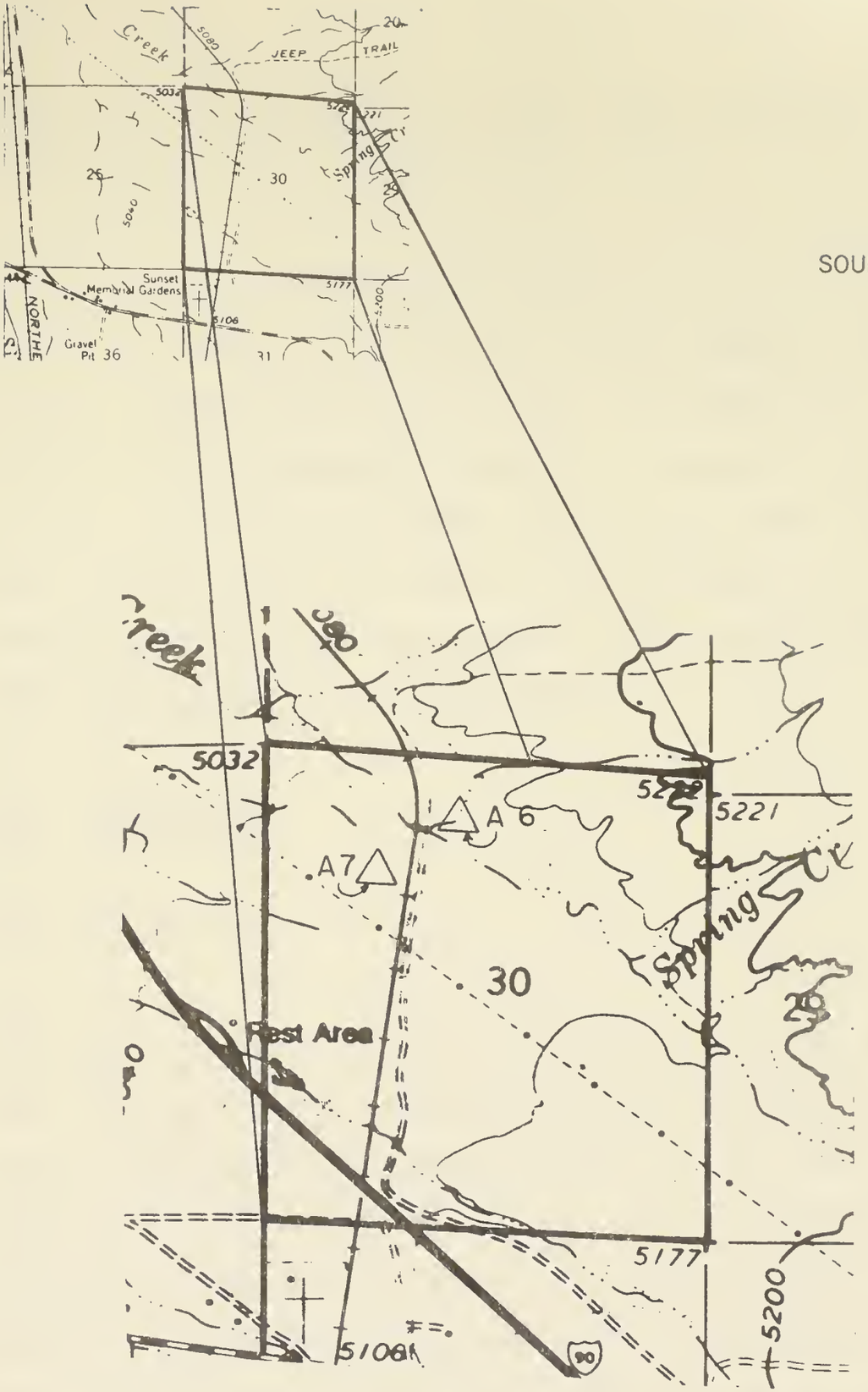
The arsenic, copper, lead, and zinc levels in alfalfa from Site T14 are elevated, but are generally nontoxic to livestock consuming such forage. The one probable exception to this assessment is for lead, which is present at a concentration detrimental to livestock (Dollhopf et al. 1986). Arsenic, iron and zinc are elevated in oats at Site T15, while copper is within the expected range. The macronutrient levels in the alfalfa (Site T14) are moderate-to-low for nitrogen, moderate for phosphorus, and high for sulfur. Nitrogen and phosphorus concentrations in oats (Site T15) are moderate-to-high, while the sulfur level is high (if not elevated).

Cadmium is the only metal which appears to be elevated at the T17 and T16 sites; such levels pose a recognized threat to livestock, particularly if it is their sole source of forage. Nitrogen and phosphorus levels are moderate at both sites, while sulfur levels are moderate-to-high in both cases.

3.4 SPANGLER'S SITES

An upgradient:downgradient pair of two sites, A6 and A7, was sampled in a cattle and sheep range pasture. Both are located on a gently sloping, southwest-facing footslope of an alluvial fan. The two sites are shown on Map 3-4.

Site A6 is well-drained, with medium permeability. Moderate erosion exists. The soil texture is coarse-loamy and is probably derived from granite. The vegetation of grasses, rabbitbrush, and leafy



N

SOURCE: USGS 15'

N

SOURCE:
USGS/USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-4
SAMPLING SITES AT SPANGLER'S

spurge is characteristic of silty range foothills. Heavy grazing effects and historic irrigation are evident.

Site A7 is well-to-excessively drained, with rapid permeability. Erosion is severe. The bare surface appears affected by wind erosion. Coarse granitic sand and fine gravel are abundant on the surface. These particles either are wind-blown sand or sediment from an old irrigation ditch located just above the site. Plant cover is less than 20% and is characterized by clumps of Basin wildrye and luxuriant leafy spurge; other species observed include needle-and-thread grass and bindweed.

3.4.1 Soils Data

3.4.1.1 Site A6

Laboratory results for Site A6 are presented in Part A of Table 3-6. Soil pH varies from very strongly acidic (within the upper 5 in.) to paraneutral at depth (12-24 in.). The sandy to loamy sand soils are neither saline nor sodic. With the exception of potassium (which is very low), macronutrient levels are generally moderate to low. With the exception of iron and manganese, total heavy metal levels exceed the upper bounds of their respective geochemical background values for soils formed in granitic rocks, mainly within the upper 5 in. of the profile. Total arsenic concentration within the 0-5 in. horizon is probably phytotoxic (Dollhopf et al. 1986). Plant-available arsenic and lead levels

TABLE 3-6
DATA SUMMARY FOR SPANGLER'S SITES (abc)

PART A. UPGRADIENT SITE, A6.

Site No./Soil Depths (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-5	139**	21.3*	4.85*	0.648	211*	18.2	9250	1.80	140	16.1	50.0*	7.26*	106*	12.8
5-12	38.0*	5.55	1.40	0.198	38.3	1.01	8050	0.252	324	12.5	8.85	0.112	48.8	4.58
12-24	19.7	0.983	<0.40	0.030	48.1	0.134	8350	<0.11	288	1.20	10.9	0.044	33.8	0.332

Soil Depths (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-5	4.62	0.30	1.2	66.5	<5	280	11.3	2.8	48.9	0.85	0.06	75.6	18.3	6.1	Sandy Loam/Loamy Sand
5-12	5.17	0.14	1.0	34.6	<5	180	4.0	2.1	56.5	0.73	0.07	92.1	5.7	2.2	Sand
12-24	6.87	0.21	3.4	15.6	<5	70	10.1	3.5	51.8	2.10	0.15	77.1	18.8	4.1	Loamy Sand

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• ELCI (VO65,VO66)	2.32±0.60	0.3±0.1	16.1±9.8	21.5±30.4	40.7±4.1	27.2±27.5	33.9±0.7	1.21±0.18	0.130±0.015	0.0998±0.0097

PART B. DOWNGRADIENT SITE, A7.

Site No./Soil Depths (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-5	358**	36.9*	13.4*	0.756	490*	57.0*	13,600	8.36	1070	35.4	650*	43.8*	615**	34.0
5-15	171**	13.3*	6.30*	1.70*	378*	108*	9500	1.26	1220	48.6	404*	25.0*	451*	88.0**
15-25	51.8*	4.41	11.9*	4.32*	146*	21.8	11,600	<0.11	920	7.44	174*	7.5	660**	252**
25-37	33.7*	0.905	1.20	0.038	37.7	0.094	18,000	<0.11	640	0.668	35.2	0.200	88.5	1.81

Soil Depths (in.)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-5	4.55	0.21	74.8	42.5	<5	390	7.6	1.9	64.4	1.18	0.10	82.1	13.5	4.4	Loamy Sand/Sand
5-15	4.86	0.16	1.0	27.9	<5	280	0.5	0.6	53.6	0.00	0.00	87.7	9.9	2.4	Sand
15-25	5.60	0.12	1.4	10.4	<5	210	1.3	2.3	47.7	0.02	0.00	91.3	5.2	3.5	Sand
25-37	6.72	0.19	3.2	8.97	<5	210	8.5	3.3	72.6	0.99	0.07	61.6	26.6	11.8	Sandy Loam

TABLE 3-6
DATA SUMMARY FOR SPANGLER'S SITES (abc) (Cont.)

PART B. DOWNGRADIENT SITE, A7(Cont.)

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• ELCI	1.478	<0.2	8.60	195	29.6	5.60	34.4	1.72	0.149	0.1188

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40+1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N, P, total S and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105+ 1°C) basis.

(b) Plant heavy metals data are given as mg/kg, "air-dried" (40+ 1°C) basis; N,P and S are as % w/w, "air Dried" basis.

(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

exceed those expected for uncontaminated soils, but do not appear to be at particularly phytotoxic concentrations. Total sulfur appears to be within expected levels, although it is on the low end of background in the 12-24 in. horizon; soluble sulfur appears to be low throughout the profile. Total arsenic concentration within the 0-5 in. horizon is probably phytotoxic (Dollhopf et al. 1986).

Plant-available correlations were calculated using the method discussed for Site T13 (Subsection 3.3.1.1). The results are presented in Table 3-7, and three major observations are presented below:

- Significant ($p<0.10$) inverse associations occur between depth and both cadmium and copper, while the inverse association between depth and arsenic is highly significant ($p<0.05$);

- Significant and highly significant inverse associations occur, respectively, between pH and manganese, and pH and zinc; and

- A highly significant positive association exists between arsenic and cadmium, while less significant ($p<0.10$) positive associations are noted for the cadmium:zinc, copper: iron, and iron:lead pairs.

TABLE 3-7
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE SPANGLER SITES.

PART A. UPGRADIENT SITE, A6[a]

Independent Variables		Dependent Variables (log[HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		-0.9974**	-0.9914*	-0.9948*	-0.9724	-0.9068	-0.9391	-0.9696
r^2		0.9948	0.9829	0.9896	0.9456	0.8223	0.8819	0.9401
• pH								
r		-0.9771	-0.9879	-0.9253	-0.9727	-0.9890*	-0.8034	-0.9992**
r^2		0.9547	0.9759	0.8562	0.9461	0.9781	0.6454	0.9984
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9983**	0.9848	0.9529	0.9349	0.9118	0.9847
	Cd	0.9983**	--	0.9729	0.9335	0.9541	0.8861	0.9933*
	Cu	0.9848	0.9729	--	0.9911*	0.8591	0.3695	0.9396
	Fe	0.9529	0.9335	0.9911*	--	0.7833	0.9934*	0.8856
	Mn	0.9349	0.9541	0.8861	0.7833	--	0.7067	0.9824
	Pb	0.9118	0.8861	0.3695	0.9934*	0.7067	--	0.8264
	Zn	0.9847	0.9933*	0.9396	0.8856	0.9824	0.8264	--

TABLE 3-7
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE SPANGLER SITES (Cont.)

PART B. DOWNGRADIENT SITE, A7.(b)

Independent Variables		Dependent Variables (log[HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		-0.9942**	-0.5066	-0.8354	-0.9480*	-0.9090*	-0.9261*	-0.4711
r^2		0.9884	0.2566	0.6978	0.8987	0.8263	0.8577	0.2219
• pH								
r		-0.9874**	-0.6784	-0.9423*	-0.8576	-0.9801**	-0.9863**	-0.6486
r^2		0.9750	0.4602	0.8879	0.7355	0.9606	0.9728	0.4207
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.5834	0.8820	0.9159*	0.9381*	0.9571**	0.5499
	Cd	0.5834	--	0.8732	0.2098	0.7347	0.7890	0.9992**
	Cu	0.8820	0.8732	--	0.6376	0.9718**	0.9791**	0.8545
	Fe	0.9159*	0.2098	0.6376	--	0.7766	0.7653	0.1701
	Mn	0.9381*	0.7347	0.9718**	0.7766	--	0.9783**	0.7096
	Pb	0.9571**	0.7890	0.9791**	0.7653	0.9783**	--	0.7638
	Zn	0.5499	0.9992**	0.8545	0.1701	0.7096	0.7638	--

(a) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.988, df=1); two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$=0.997, df=1).
(b) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.900, df=2); two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$=0.997, df=2).

3.4.1.2 Site A7

Laboratory results for Site A7 are presented in Part B of Table 3-6. Soil reaction increases from very strongly acidic surface (0-15 in.) values to paraneutrality at depth (25-37 in.). None of the loamy sand, sand, or sandy loam horizons exhibit salinity or sodium hazards. Rooting zone macronutrient levels are very low to low. With the exception of iron and manganese, total heavy metal levels exceed the upper bounds of their respective geochemical background values, within the upper 25 in. of soil. Total arsenic contamination extends to the base of the sampled profile. Furthermore, total arsenic levels are phytotoxic within the upper 15 inches of the profile, while total zinc levels are phytotoxic within the 0-5 in. and 15-25 in. horizons (Dollhopf et al. 1986). Plant-available levels of arsenic, cadmium, copper, lead, and zinc present within the upper 25 in. of soil are often greater than expected, and zinc levels within the 5-to 25-inch horizons are probably phytotoxic. These data indicate the relatively high mobility of cadmium and zinc, and the lesser mobility of arsenic, copper, and lead. Total sulfur levels are within expected geochemical background, while soluble sulfur is low throughout the profile.

3.4.2 Plant Data

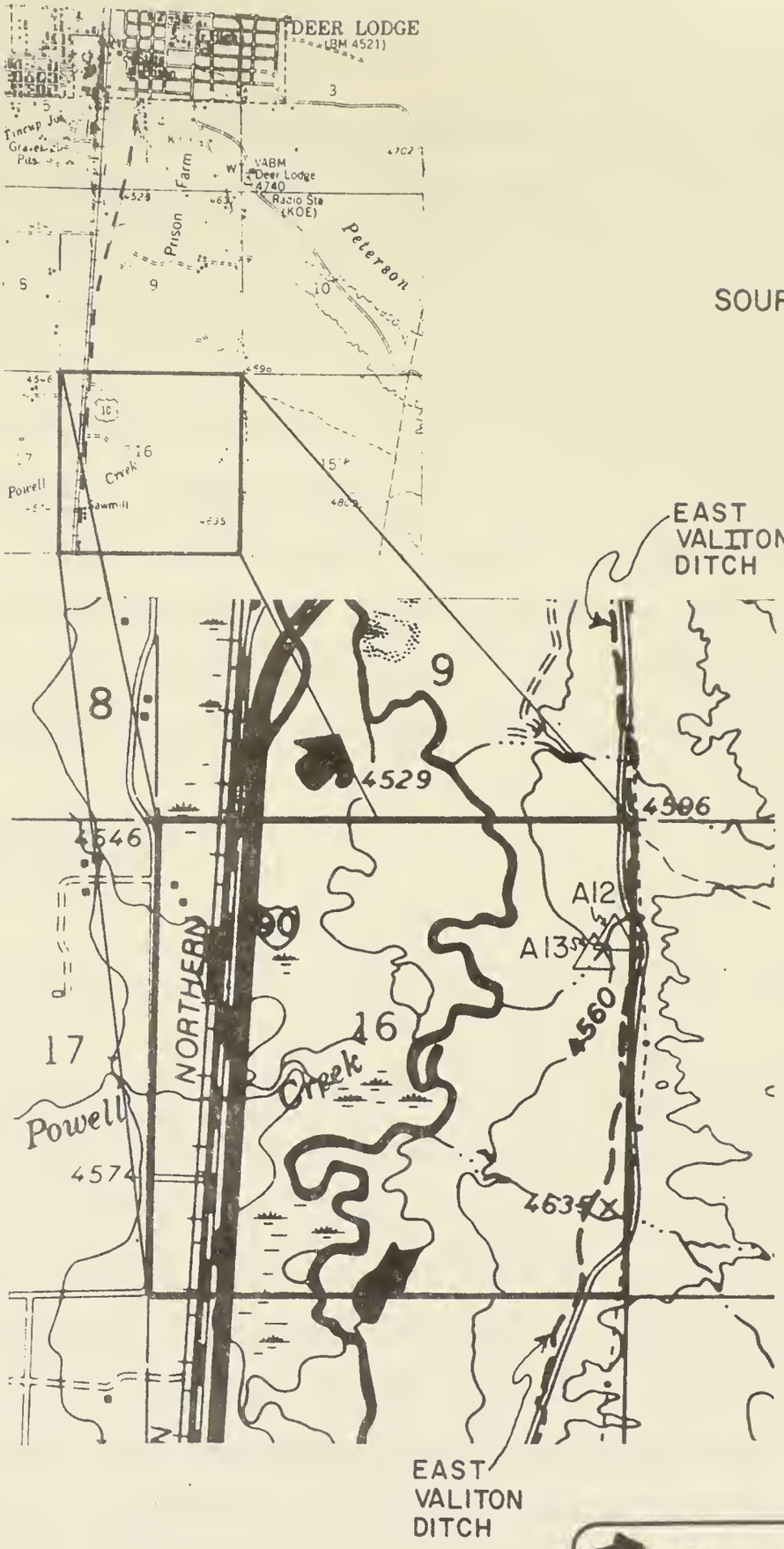
Arsenic appears to be slightly above expected (background) levels in Site A6, while cadmium and copper approach their respective upper bounds for biogeochemical background. Lead levels at the site

are occasionally elevated and could be phytotoxic (ie., at levels exceeding 30 µg/g, Dollhopf et al. 1986). The copper levels may adversely affect sheep, if this forage served as their sole food source. Macronutrient levels are generally near the lower bounds of their respective background values, and nitrogen may be borderline deficient.

At Site A7, all heavy metals occur within their respective biogeochemical background levels, despite elevated plant-available concentrations within the rooting zone. Macronutrient levels are generally near the lower bounds of their respective background values for all three elements.

3.5 FORSEN'S SITES

Similar to the Spangler sites, one upgradient:downgradient pair of sampling sites was utilized in Forsen's pastureland. They are numbered A12 and A13 and are shown on Map 3-5. A12 is located above the remains of the E. Valiton Ditch, and A13 is below it. Both are situated on a northwest facing alluvial fan of moderate slope; A13 is about 2 ft lower in elevation than A12. Both are well-drained sites of moderate permeability, but while Site A12 is moderately eroded, A13 is severely eroded. The soil at both sites is coarse-loamy, probably derived from coarse gravels of volcanic origin, overlying poorly consolidated bedded tuff.



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SOURCE: USGS 15'

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SOURCE:
USGS / USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-5
SAMPLING SITES AT FORSEN'S

On Site A12, the vegetation is representative of a moderately grazed silty range foothills site. Grass species include Basin wildrye, bluebunch wheatgrass, and blue grama; shrub species are wild rose and rubber rabbitbrush.

Site A13 is poorly vegetated by such species as Basin wildrye, bluebunch wheatgrass, leafy spurge, and thistles. A possible explanation of the great difference between A13's and A12's vegetation could be in the evidence of a historic breach in the ditch during operation. The breach could have released large quantities of sediment and water which were laden with heavy metals onto Site A13.

3.5.1 Soils Data

3.5.1.1 Site A12

The laboratory results for Site A12 are presented in Table 3-8, Part A. Soil reaction increases from slightly acidic, at the surface, to moderately alkaline at depth (14-40 in). Texture of these non-saline and non-sodic soils ranges from silty loam to sandy loam. With the exception of surficial potassium, macronutrient levels are generally low to very low. Total heavy metal levels in the 0-5 in. horizon exceed--with the exception of iron and manganese--the upper bounds for the respective geochemical background values; arsenic is present at phytotoxic concentrations. The shallow depth of contamination may be due to the absorptive capacity of the relatively fine-textured 0-5 in. horizon, which may explain the relatively

TABLE 3-8

DATA SUMMARY FOR FORSEN'S SITES[a,b,c]

PART A. UPGRADIENT SITE, A12

Soil Depths (in)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-5 (n=1)	112**	9.03*	4.05*	0.522	665*	8.10	16,600	0.338	665	10.2	62.5*	0.780	220	13.0
5-14 (n=2)	45.2±2.9	2.98±0.05	1.14±0.44	0.066±0.023	97.6±6.2	1.237±0.358	16,650±5162	0.119±0.010	643±24	2.82±1.52	24.2±6.0	0.154±0.153	73.8±5.4	0.83±0.17
14-40 (n=2)	10.6±0.4	<0.720	0.39±0.01	0.015±0.010	39.8±3.2	1.62±0.06	16,450±5728	2.785±1.322	632±144	2.745±1.266	25.4±8.1	0.354±0.042	63.5±6.4	0.252±0.090

Soil Depths (in)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	Ke	Na	SAR	Sand	Silt	Clay	Textural Class
0-5 (n=1)	6.23	0.41	16.4	52.1	<5	80	34.0	8.4	240.3	39.65	0.04	40.4	50.3	9.3	Silt Loam/Loam
5-14 (n=2)	6.42±0.01	0.39±0.05	4.4±0.6	24.6±1.9	<8	185±120	33.0±5.1	9.2±1.8	147.8($\bar{x}$)	1.7±0.6	0.07($\bar{x}$)	50.0±0.2	41.9±0.1	8.0±0.4	Loam
14-40 (n=2)	7.94±0.01	1.24±0.09	11.8±1.1	11.0±1.9	18±7	120±113	185.9±21.2	53.3±3.5	93.0($\bar{x}$)	10.92±0.99	0.18($\bar{x}$)	57.4±3.2	34.5±3.3	8.0±0.4	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• ELCI	0.805	<0.2	6.50	112	29.0	<4.5	23.4	1.53	0.217	0.0874

PART B. DOWNGRADIENT SITE, A13

Soil Depths (in)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
"0-4" (n=4)	454±72**	29.3±3.5*	14.8±3.9*	1.03±0.24*	2445±381*	657.5±151.8*	19,325±3743	1.53±0.82	590±93	167±51*	260±31*	1.11±0.83	564±69**	154.5±61.3**
3-8 (n=2)	173±20**	15.8±5.1*	6.76±0.97*	0.812±0.110	1615±50*	509.0±35.4*	16,500±6364	0.32±0.02	578±11	96.8±8.8*	101.1±32.4*	0.848±0.062	402±11*	96.0±12.7**
8-18 (n=1)	34.4	2.33	0.980	0.180	148	6.94	22,300	1.14	618	2.48	34.5	<0.26	223*	16.6
18-38 (n=1)	18.6	<0.687	0.545	0.044	75.7	12.5	19,500	2.38	421	2.98	24.2	0.310	75.2	5.48

Soil Depths (in)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	Ke	Na	SAR	Sand	Silt	Clay	Textural Class
"0-4" (n=4)	4.46±0.16	3.41±1.60	49.2±38.6	27.4±2.9	2630±1722	1830±840	452.9±221.0	163.3±103.5	44.0($\bar{x}$)	41.42±21.83	0.42($\bar{x}$)	52.1±1.9	32.0±2.8	15.9±2.2	Sandy Loam/Loam
3-8 (n=2)	4.79±0.14	1.45±0.18	18.4±7.6	23.4±0.5	60±9	170±226	177.9±31.1	53.7±10.0	76.4($\bar{x}$)	15.87±2.62	0.27($\bar{x}$)	55.8±1.8	31.5±8.9	12.7±7.1	Sandy Loam/Sandy Clay Loam
8-18 (n=1)	6.42	2.37	26.8	11.4	748	460	537.9	136.8	108.3	36.92	0.37	52.4	35.6	12.0	Sandy Loam/Loam
18-38 (n=1)	7.93	1.84	33.2	5.87	191	50	302.9	81.8	76.4	33.82	0.45	62.8	26.5	10.7	Sandy Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• ELCI	0.852	<0.2	7.95	1300	47.6	<4.5	42.4	1.49	0.196	0.0945

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40±1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N, P, total S and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105± 1°C) basis.

(b) Plant heavy metals data are given as mg/kg, "air-dried" (40± 1°C) basis; N,P and S are as % w/w, "air-dried" basis.

(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

low plant-available levels (excepting arsenic), despite the relatively high total concentrations. Total sulfur levels are approaching the low end of the expected background range; soluble sulfur levels are generally low.

Plant available correlations were calculated using the methodology described in subsection 3.4.1.1. The results are shown in Table 3-9, Part A, which indicates three major observations:

- Highly significant ($p<0.05$) and significant ($p<0.10$) inverse associations exist between depth and arsenic, and depth and cadmium respectively;

- No significant associations exist between pH and any of the measured elements; and

- Significant positive associations exist between the cadmium: zinc and copper:manganese pairs.

3.5.1.2 Site A13

The laboratory results for this site are presented in Part B of Table 3-8. The pH varies from very strongly acidic within the upper 8 in. to moderately alkaline at depth (18-36 in.) The texture of these non-saline and non-sodic soils is generally sandy loam. Potassium and phosphorus are very low, while nitrogen is present at moderate concentrations. With the exception of iron and manganese,

TABLE 3-9
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE FORSEN'S SITES.(a)

PART A. UPGRADIENT SITE, A12(b)

Independent Variables		Dependent Variables (log[HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		-0.9975**	-0.9954*	-0.7920	0.8046	-0.8749	-0.4869	-0.9749
r^2		0.9950	0.9908	0.6273	0.6474	0.7654	0.2371	0.9504
• pH								
r		-0.9390	-0.8692	-0.8312	0.9079	-0.5997	-0.0864	-0.7982
r^2		0.8817	0.7555	0.6909	0.8243	0.3596	0.0075	0.6371
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9862	-0.4205	-0.7084	0.8383	0.4236	0.9566
	Cd	0.9862	--	0.8833	-0.5208	0.9169	0.5676	0.9916*
	Cu	-0.4205	0.8463	--	-0.0594	0.9886*	0.9189	0.9080
	Fe	-0.7084	-0.5208	-0.0594	--	-0.2090	0.8735	-0.4722
	Mn	0.8383	0.9169	0.9886*	-0.2090	--	0.8490	0.9607
	Pb	0.4236	0.5676	0.9189	0.8735	0.8490	--	0.0239
	Zn	0.9566	0.9916*	0.9080	-0.4722	0.9607	0.0239	--

TABLE 3-9
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE FORSEN'S SITES.[a] (Cont.)

PART B. DOWNGRADIENT SITE, A13[(c)]

Independent Variables		Dependent Variables (log[HM]s						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		-0.9838**	-0.9656**	-0.8712	0.3889	-0.9104*	-0.8979	-0.9800**
r^2		0.9679	0.9324	0.7590	0.1512	0.8288	0.8062	0.9604
• pH								
r		-0.9931**	-0.9794**	-0.8340	0.5990	-0.9095**	-0.8802	-0.9944**
r^2		0.9862	0.9593	0.6956	0.3588	0.8272	0.7748	0.9888
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9910**	0.9181*	-0.5352	0.9459*	0.9256*	0.9998**
	Cd	0.9910**	--	0.8756	-0.6139	0.9045*	0.8751	0.4801
	Cu	0.9181*	0.8283	--	-0.2213	0.9962**	0.9940**	0.9188**
	Fe	-0.5352	-0.6139	-0.2213	--	-0.6720	-0.4176	-0.7412
	Mn	0.9459*	0.9045*	0.9962**	-0.6720	--	0.9966**	0.2231
	Pb	0.9256*	0.8751	0.9940**	-0.4176	0.9966**	--	-0.6276
	Zn	0.9998**	0.4801	0.9188*	-0.7412	0.2231	-0.6276	--

(a) Correlation values were calculated by converting the arithmetic mean laboratory data to respective $\log_{10}$ data.
(b) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.988, df=1); two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$=0.997, df=1).
(c) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.900, df=2); two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$=0.950, df=2).

total heavy metals exceed the upper bounds of their respective geochemical background values. This contamination extends throughout the upper 8 in. of soil for these elements and into the upper 18 in. for zinc. The relative degree of heavy metal contamination appears, on the average, to be several fold that observed at site A12. Total arsenic and zinc levels are phytotoxic within the upper 4 in. of the soil profile, and arsenic phytotoxically extends down to 8 in. Surface (0-8 in) plant-available heavy metal levels exceed the upper bounds of their respective values for arsenic, cadmium (0-4 in., only), copper, manganese, and zinc. The cumulative concentration of copper, manganese and zinc is sufficiently high to be phytotoxic. Total sulfur levels appear slightly elevated within the upper 4 in. of the profile, but changes from moderate to low concentrations with increasing depth. Sulphate ion levels are elevated throughout the profile, except for the 3-8 in. horizon.

Plant-available correlations are shown in Part B of Table 3-9. The three major observations are as follows:

- Highly significant ($p<0.05$) inverse associations exist between depth and arsenic, cadmium, and zinc, while a significant ($p<0.10$) inverse association exists between depth and manganese;

- Highly significant inverse associations exist between pH and arsenic, cadmium, and zinc, while a significant inverse association exists between depth and manganese; and

- Highly significant positive associations exist among arsenic, copper, manganese, and lead (with each other), and sometimes between these elements and cadmium and zinc.

3.5.2 Plant Data

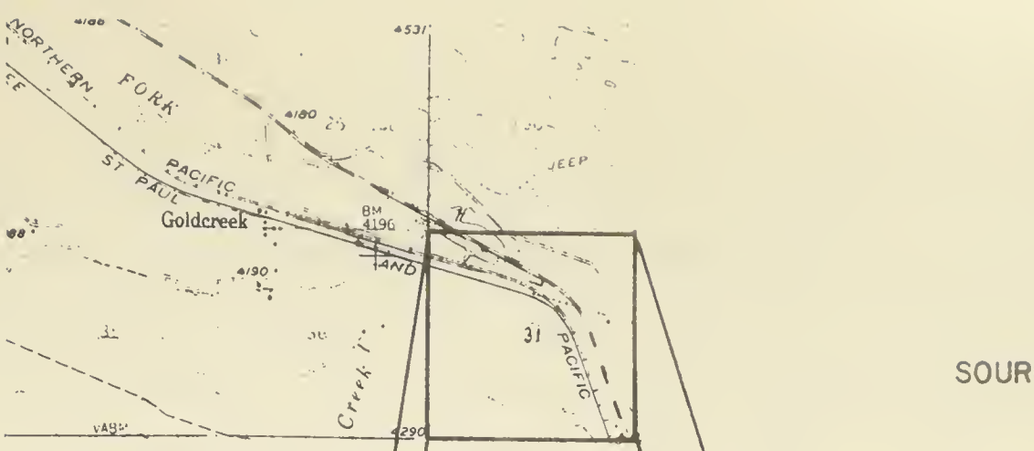
All heavy metal levels are generally within their respective biogeochemical background values at Site A12. However, all macronutrients are at or approaching their respective lower bounds for the particular background levels. Nitrogen and sulfur may be borderline deficient; the nitrogen:sulfur ratio indicates a potential sulfur deficiency.

At Site A13, plant iron is quite elevated, while the other heavy metal levels are within their expected biogeochemical background values. These levels are, however, greater than the respective concentrations observed in plant material from site A12.

Nutrient levels at Site A13 all approach the lower bounds of their respective background values. Nitrogen and sulfur appear to be borderline deficient; this assessment regarding sulfur levels is supported by the nitrogen:sulfur ratio of >13.

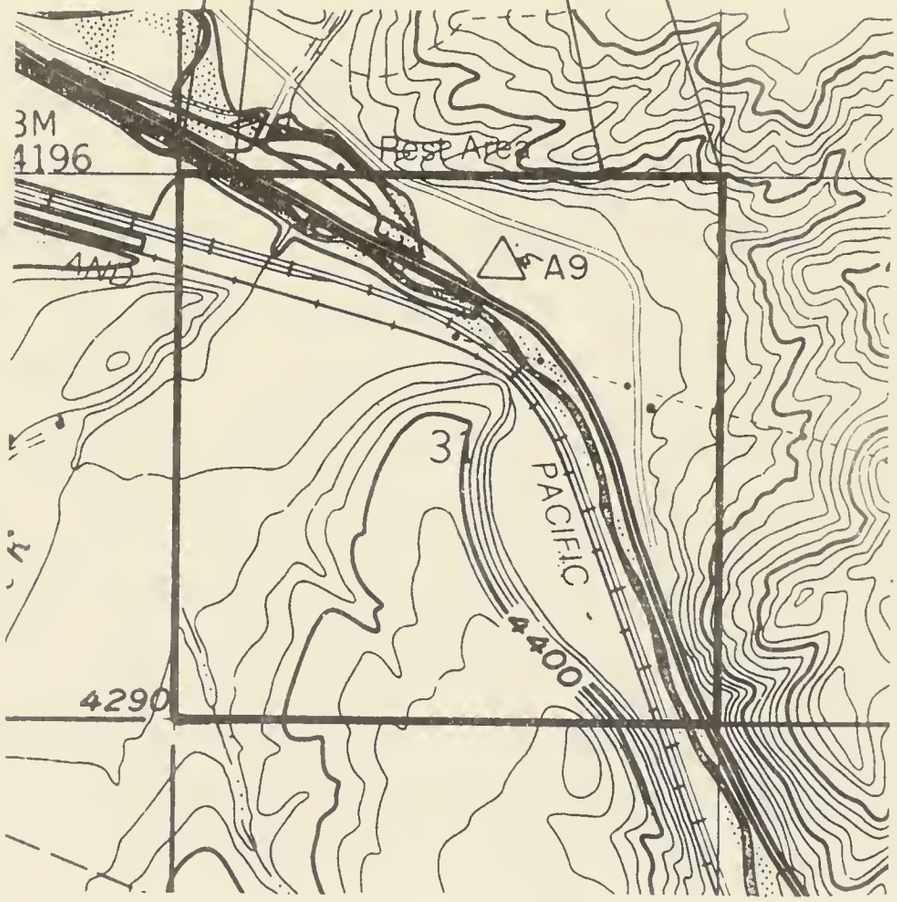
3.6 DUTTON'S SITE

Only one site was sampled in Dutton's wet meadow, shown on Map 3-6. the site is on the nearly level, west-facing floodplain of the



N

SOURCE: USGS 15'



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SOURCE:
USGS/USFS 7.5'

SILVER BOW CREEK

REMEDIAL INVESTIGATION

MAP 3-6
SAMPLING SITE AT DUTTON'S

Clark Fork River. It is poorly drained, and exhibits medium permeability, and is slightly eroded. A9's soil is fine-loamy, and the bare surface showed salt seeps. Mill tailings overlay an older surface horizon. The vegetation is representative of a moderately grazed, subirrigated, wetland range site. Grass species include Kentucky bluegrass and smooth brome; sedge also is abundant. The present land use is irrigated hay for livestock forage.

3.6.1 Soils Data

The laboratory results for this site are presented in Table 3-10. The very strongly acidic surface (0-5 in.) horizon overlays 13 in. of extremely acidic (pH<4.5) materials, much of which is mill tailings. The lowest buried, 18-26 in., horizon's pH is slightly acidic. With the exception of the loamy sand A12 horizon, the profile's textural class is silty loam. The soil is neither saline nor sodic. Nitrogen levels are moderate, while the other macronutrient levels are very low. With the exception of iron, all of the heavy metals have total levels that exceed the upper limit of their respective geochemical background values. Except for total manganese in the 18-26 in. horizon, contamination by the other elements extends throughout the profile. With the exception of total zinc within the 10-18 in. horizon, total zinc and arsenic levels are phytotoxic throughout the profile. With the exception of copper, the uppermost and lowermost horizons exhibit plant-available levels which most commonly exceed their respective geochemical background levels.

TABLE 3-10
DATA SUMMARY FOR DUTTON'S SITE (abc)

Soil Depth (in.)	As		Cd		Cu		Fe		Mn		Pb		Zn	
	T	P	T	P	T	P	T	P	T	P	T	P	T	P
0-5	251**	3.13	8.18*	0.458	2100*	502*	15,600	3.32	992	200*	170*	1.38	1220**	260**
5-10	234**	2.93	6.10*	0.112	499*	60.0*	13,600	18.3	585	17.0	182*	2.98	565**	26.0
10-18	541**	2.59	14.8*	0.112	495*	43.6*	17,300	10.2	104	8.6	574*	<0.13	279*	26.2
18-26	426**	22.8*	23.0*	4.76*	6300*	954*	17,500	1.23	2510*	23.0	550*	19.1*	2320**	432**

Soil Depth(in)	pH	EC	N	P	SO_4^{-2}	S	Ca	Mg	K_e	Na	SAR	Sand	Silt	Clay	Textural Class
0-5	4.59	2.51	20.4	1.79	983	970	420.9	121.8	36.1	54.52	0.60	45.4	48.5	6.1	Silt Loam
5-10	3.89	0.98	3.2	<0.35	620	1280	130.9	29.3	6.9	23.92	0.49	82.1	16.9	1.0	Loamy Sand
10-18	3.86	0.86	5.4	0.52	839	2080	106.9	21.1	17.2	19.42	0.45	9.7	74.3	16.0	Silt Loam
18-26	6.02	1.21	10.0	10.70	176	1310	153.9	26.1	54.4	16.62	0.33	19.4	67.3	13.3	Silt Loam

Plant Analyses	As	Cd	Cu	Fe	Mn	Pb	Zn	N	P	S
• BRIN	<0.365	0.7**	20.6	48.2	85.0	<4.5	285*	3.92	0.265	0.2808

(a) Total (T) and plant available (P) soils-related heavy metals data are given as mg/kg, "air-dried" (40+1°C) basis; pH in standard units; EC in mmhos/cm @ 25°C; N, P, total S and SO_4^{-2} ion as µg/g "air-dried" soil; Ca, Mg, K_e (exchangeable K) and Na as mg/L in soil extract; sodium absorption ratio (SAR) is dimensionless; mechanical analyses (sand, silt and clay) as % (w/w), oven dried (105+ 1°C) basis.

(b) Plant heavy metals data are given as mg/kg, "air-dried" (40+ 1°C) basis; N,P and S are as % w/w, "air-dried" basis.

(c) An asterisk (*) signifies a biogeochemically elevated concentration of a particular element, as judged by literature review. Two asterisks (**) signifies probable phytotoxic conditions in plant materials and/or soils.

Copper, manganese, and zinc are each present at phytotoxic levels in the 0-5 in. horizon; copper and zinc are each present at phytotoxic levels generally throughout the profile. With the exceptions of iron and manganese, the other plant-available heavy metal levels are clearly elevated within the 18-26 in. horizon. The metal-absorbing capacity of this silt loam might explain its function as a "sink" for those metals migrating down through the profile.

Alternatively, early 20th century rates of tailings deposition (within this meander cut-off in the Clark Fork River floodplain) may have exceeded those of more recent years. For example, the tailings observed at depth (10-18") may have resulted from catastrophic flood events occurring within the period 1905-1920. Deposition rates since then may have been less dramatic, thus allowing gradual mixing of soil particles and mill tailings over time.

Total sulfur levels are generally within the expected background range; the one exception is the 10-18 in. horizon, with a sulfur level at the upper bounds of the expected concentration. Soluble sulfur levels are slightly above their respective expected values, except for the moderate level within the 18-26 in. horizon. It is hypothesized that such levels are from the weathering of pyritic materials, especially those associated with the mill tailings.

Plant available correlations were calculated, using depth, pH and log [HM] levels as the independent variables and log [HM] levels as

the dependent variable. The results are shown in Table 3-11. Three major observations include the following:

- No significant ($p>0.10$) associations exist between depth and heavy metal levels;

- Highly significant ($p<0.05$) positive associations exist between pH and arsenic, cadmium, and copper, while a significant ($p<0.10$) negative association occurs between pH and iron; and

- Highly significant negative associations exist between iron and cadmium, plus zinc; a highly significant positive association exists between copper and zinc, while significant associations ($\pm$) occur between the following element pairs: arsenic/cadmium (+); cadmium/copper (+); cadmium/zinc (+); and copper/iron (-).

3.6.2 Plant Data

The only heavy metal concentrations which are elevated include cadmium and zinc. Toxicity to livestock is possible due to the cadmium level, particularly if it serves as their only source of forage. The nutrient concentrations are within their respective background ranges. More specifically, nitrogen and sulfur levels are moderate-to-high, while phosphorus level is moderate.

TABLE 3-11
PLANT AVAILABLE CORRELATIONS SUMMARY FOR THE DUTTON SITE [a]

Independent Variables		Dependent Variables (log[HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
• Depth								
r		0.7253	0.5125	0.1354	-0.3835	-0.6810	0.3006	0.1328
r^2		0.5261	0.2626	0.0183	0.1471	0.4638	0.0904	0.0176
• pH								
r		0.9600**	0.9989**	0.9977**	-0.9437*	0.2251	0.6972	0.8889
r^2		0.9216	0.9978	0.9954	0.8906	0.0507	0.4861	0.7901
		As	Cd	Cu	Fe	Mn	Pb	Zn
• log[HM]s	As	--	0.9460*	0.7492	-0.8273	-0.0041	0.8046	0.7256
	Cd	0.9460*	--	0.9184*	-0.9567**	0.2652	0.7778	0.9086*
	Cu	0.7492	0.9184*	--	-0.9438*	0.6249	0.7199	0.9957**
	Fe	-0.8273	-0.9567**	-0.9438*	--	-0.4134	-0.5956	-0.9584**
	Mn	-0.0041	0.2652	0.6249	-0.4134	--	0.2176	0.6341
	Pb	0.8046	0.7778	0.7199	-0.5956	0.2176	--	0.6547
	Zn	0.7256	0.9086*	0.9957**	-0.9584**	0.6341	0.6547	--

(a) One asterisk (*) signifies 90% confidence ($P_{0.10}$=0.900, df=2); two asterisks (**) signifies $\geq$ 95% confidence ($P_{0.05}$=0.950, df=2).

3.7 DATA SYNTHESIS AND DISCUSSION

The following two assumptions were made at project onset:

- Site-specific categorizations as being either "upgradient" (uphill) or "downgradient" (downhill) from a hypothesized source of waterborne heavy metals contamination were essentially correct; and

- Such categorizations were justified on the basis of the following analytical parameters: pH, total and soluble (SO_4^{-2}) sulfur, acid digestable (total) and extractable (plant-available) heavy metal levels in soils, and total heavy metal levels in plant materials.

3.7.1 Evaluation of Project Assumptions

The Remedial Investigation (RI) data first was used to test the correctness of the project assumptions; the relevent data are presented in Tables 3-12 and 3-13 for soils and plant materials, respectively. These data are further summarized in Table 3-14. Inspection of these tables yields several important observations:

- Soil and plant heavy metal levels are more frequently elevated in the downgradient than upgradient sites;

TABLE 3-12
SUMMARY OF CRITICAL SOILS DATA[a]

PART A. UPGRADIENT SITES

Site No./ Depth (in.)	pH	Total S	SO_4^{-2}	PARAMETERS[b] As T	As P	Cd T	Cd P	Cu T	Cu P	Fe T	Fe P	Mn T	Mn P	Pb T	Pb P	Zn T	Zn P
A10(above SBC floodplain)																	
0-5	6.62	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
A1(above SBC floodplain)																	
0-12	7.95	2210	6750	--	--	--	--	--	--	--	--	--	--	--	--	--	--
12-22	9.14	--	1330	--	--	--	--	--	--	--	--	--	--	--	--	--	--
22-28	9.50	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T12(Yellow Ditch)																	
0-5	6.19	--	--	--	--	5.35*	1.19*	444*	(4.88)	--	--	--	--	127*	(5.66)	347*	(26.2)
5-17	6.67	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
T14(Yellow Ditch)																	
0-4	4.03	--	--	214*	31.1*	6.55*	(0.976)	214*	(21.0)	--	--	(500)	80.8*	110*	(5.04)	158*	(17.2)
T17(Yellow Ditch)																	
0-5	5.74	--	--	115*	(3.39)	7.18*	(0.808)	339*	(10.1)	37,700*	(0.226)	--	--	168*	(1.17)	349*	(13.7)
A6(watson Ditch)																	
0-5	4.62	--	--	139*	21.3*	4.85*	(0.648)	211*	(18.2)	--	--	--	--	50.0*	7.26*	106*	(12.8)
5-12	5.17	--	--	38.0*	(5.55)	--	--	--	--	--	--	--	--	--	--	--	--
A12(E. Valiton Ditch)																	
0-5	6.23	--	--	112*	9.03*	4.05*	(0.522)	665*	(8.10)	--	--	--	--	62.5*	(0.780)	220*	(13.0)

TABLE 3-12
SUMMARY OF CRITICAL SOILS DATA[a] (Continued)

PART B. DOWNGRADIENT SITES

Site No./ Depth (in.)	pH	Total S	SO_4^{-2}	As		Cd		Cu		Fe		Mn		Pb		Zn	
				T	P	T	P	T	P	T	P	T	P	T	P	T	P
PARAMETERS[b]																	
A11(SBC floodplain)																	
0-9	6.90	5650*	202*	2560*	95.9*	74.0*	2.44*	2060*	402*	--	--	--	--	667*	(0.624)	6420*	514*
A2(SBC floodplain)																	
0-6	7.98	--	--	80.0*	9.65*	5.99*	1.39*	420*	128*	--	--	--	--	387*	62.0*	624*	(37.8
A3(SBC floodplain)																	
0-15	7.33	3780*	886*	652*	8.62*	27.8*	1.68*	3140*	362*	--	--	5650*	(7.36)	950*	29.2*	4600*	109*
15-30	7.23	2450*	1390*	187*	12.7*	10.1*	2.32*	1200*	(22.8)	--	--	1850*	(5.04)	471*	28.6*	1850*	162*
30-46	6.94	2630*	1150*	--	--	--	--	--	--	--	--	--	(55.8)	--	--	246*	(13.1
T13(Yellow Ditch)																	
0-3	5.59	--	--	--	--	10.8*	3.74*	745*	93.0*	--	--	1440*	(52.6)	50.0*	(0.512)	775*	286*
3-10	6.45	--	--	--	--	4.85*	3.64*	318*	175*	--	--	--	--	--	--	316*	112*
10-18	5.99	--	--	--	--	3.37*	1.07*	207*	(18.2)	--	--	--	--	78.2*	(5.00)	419*	102*
T15(Yellow Ditch)																	
0-8	7.72	--	--	172*	(14.8)	6.45*	(0.928)	325*	79.2*	--	--	--	--	122*	15.0*	264*	(23.6)
T16(Yellow Ditch)																	
0-4	4.02	--	--	249*	20.0*	8.20*	1.24*	391*	66.0*	--	--	(835)	79.6*	229*	13.4*	284*	(31.2)
A7(Watson Ditch/SBC)																	
0-5	4.55	--	--	358*	36.9*	13.4*	(0.756)	490*	57.0*	--	--	--	--	650*	43.8*	615*	(34.0)
5-15	4.86	--	--	171*	13.3*	6.30*	1.70*	378*	108*	--	--	--	--	404*	25.0*	451*	88.0*
15-25	5.60	--	--	51.8*	(4.41)	11.9*	4.32*	146*	(21.8)	--	--	--	--	174*	(7.5)	660*	252*
25-37	6.72	--	--	33.7*	(0.905)	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3-12
SUMMARY OF CRITICAL SOILS DATA[a] (Continued)

Site No./ Depth (in.)	pH	Total S	SO_4^{-2}	PARAMETERS[b] As T	As P	Cd T	Cd P	Cu T	Cu P	Fe T	Fe P	Mn T	Mn P	Pb T	Pb P	Zn T	Zn P
A13(E. Valiton Ditch/CFR)																	
:0-4	4.46	1830*	2630*	454*	29.3*	14.8*	1.03*	2445*	657.5*	--	--	(590)	167*	260*	(1.11)	564*	154.5*
:3-8	4.79	--	--	173*	15.8*	6.76*	(0.812)	1615*	509.0*	--	--	(578)	96.8*	101.1*	(0.848)	402*	96.0*
:8-18	6.42	748*	(460)	--	--	--	--	--	--	--	--	--	--	--	--	223*	(16.6)
A9(CFR floodplain)																	
:0-5	4.59	(970)	983*	251*	(3.13)	8.18*	(0.458)	2100*	502*	--	--	(992)	200*	170*	(1.38)	1220*	260*
:5-10	3.89	(1280)	620*	234*	(2.93)	6.10*	(0.112)	499*	60.0*	--	--	--	--	182*	(2.98)	565*	(26.0)
:10-18	3.86	2080*	839*	541*	(2.59)	14.8*	(0.112)	495*	43.6*	--	--	--	--	574*	(<0.134)	279*	(26.2)
:18-26	6.02	--	--	426*	22.8*	23.0*	4.76*	6300*	954*	--	--	2510*	(23.0)	550*	19.1*	2320*	432*

(a) For the heavy metals, plus sulfur data, an asterisk (*) signifies a geochemically elevated level; a value within parentheses signifies a geochemically "expected" level; while a dash(-) represents the presence of non-pertinent data.
(b) pH is standard units; all other parameters in mg/kg, air-dried basis.

TABLE 3-13
SUMMARY OF CRITICAL PLANT DATA[a]

PART A. UPGRADIENT (UPHILL) SITES

Site/Species	Elements[b] As	Cd	Cu	Fe	Mn	Pb	Zn
A10(above SBC)							
•POPR	--	--	--	--	--	--	--
A1(SBC floodplain)							
•AGSP	--	--	--	--	--	112*	--
T12(Yellow Ditch)							
•CAREX sp.	--	--	--	--	--	--	--
T14(Yellow Ditch)							
•MESA	2.193*	--	41.7*	--	--	51.0*	60.0*
A6(Watson Ditch)							
•ELCI	--	--	--	--	--	--	--
A12(E. Valiton Ditch)							
•ELCI	--	--	--	--	--	--	--

PART B. DOWNGRADIENT (DOWNHILL) SITES

A11(SBC floodplain)							
•CAREX sp.	--	--	--	479*	--	--	150*
A2(SBC floodplain)							
•CAREX sp.	--	--	--	--	--	--	--
A3(SBC floodplain)							
•ELCI	20.04*	--	124*	--	--	65.0*	182*
•CAREX sp.	6.635*	--	--	--	--	--	194*
T13(Yellow Ditch)							
•CAREX sp.	--	--	80.5*	--	--	--	329*
T15(Yellow Ditch)							
•AVSA	10.86*	--	--	222*	--	--	63.0*
T16(Yellow Ditch)							
•MESA	--	--	--	--	--	--	--
A7(Watson Ditch)							
•ELCI	--	--	--	--	--	--	--
A13(E. Valiton Ditch)							
•ELCI	--	--	--	--	--	--	--
A9(Clark Fork River floodplain)							
•BRIN	--	--	--	--	--	--	285*

(a) An asterisk (*) signifies a biogeochemically elevated level, while a dash (-) represents non-pertinent data.
(b) All concentrations in mg/kg, air-dried basis.

TABLE 3-14
CONDENSATION OF KEY DATA FROM TABLES 3-12 AND 3-13

PART A. UPGRADIENT (UPHILL) SITES

pH≤5.5	Elev. S.	Elev. SO_4^{-2}
3	1	2

PARAMETERS

Elev. Heavy Metals in Soils[a]

Element	T* x P*	T* x P	T x P*
As	3	2	0
Cd	1	4	0
Cu	0	5	0
Fe	0	1	0
Mn	0	0	1
Pb	1	4	0
Zn	0	5	0

Elev. Heavy Metals in Plant Materials

Element	No. of Occurences
As	1
Cd	0
Cu	1
Fe	0
Mn	0
Pb	2
Zn	1

PART B. DOWNGRADIENT (DOWNHILL) SITES

pH≤5.5	Elev. S.	Elev. SO_4^{-2}
8	7	8

PARAMETERS

Elev. Heavy Metals in Soils[a]

Element	T* x P*	T* x P	T x P*
As	10	6	0
Cd	12	6	0
Cu	15	3	0
Fe	0	0	0
Mn	0	4	4
Pb	8	9	0
Zn	12	8	0

Elev. Heavy Metals in Plant Materials

Element	No. of Occurences
As	3
Cd	0
Cu	2
Fe	2
Mn	0
Pb	1
Zn	5

(a) The asterisk (*) signifies a biogeochemically elevated condition for a given element's acid extractable (T) or plant available (P) concentration in soils.

- Heavy metals contamination in upgradient soils appears to be generally limited to the upper 6 in. of soil, while contamination in downgradient soils commonly extends to 24 in., and may occur to a depth of 46 in.

- By themselves, pH and sulfur level measurements are not reliable indicators of probable heavy metals contamination--the latter parameters can be elevated without the presence of strongly acidic soil reaction or geochemically elevated levels of total or soluble sulfur; and

- If plant zinc is elevated at a downgradient site, arsenic also is elevated in the majority of cases.

3.7.2 Evaluation of Metals Correlations

General relationships among plant-available heavy metal levels, as well as with depth and pH were evaluated. This effort was accomplished by compiling pertinent data from the correlation tables found throughout Section 3.0.

Site-specific correlations (for both upgradient and downgradient categories) for each specific pair (eg., arsenic:cadmium) were evaluated using the following system:

- A non-significant ($p>0.10$) correlation was valued at 0.;
- A significant ($0.1 \leq p = 0.05$) correlation was valued at $\pm$ 0.90, depending upon the sign of the particular r; and
- A highly significant ($p<0.05$) correlation was valued at $\pm$ 0.95, again depending upon the sign of the particular r.

In some cases, application of this system resulted in zero when equal values of opposite sign were added together. The results for these efforts are shown in Table 3-15. Regarding the upgradient sites, three important observations are made:

- A consistently strong inverse association exists between depth and both cadmium and arsenic;
- A consistently strong inverse association exists between pH and both manganese and zinc; while
- Strong positive associations exist between the cadmium:zinc; arsenic:cadmium; copper:iron; and copper:manganese pairs.

Similarly, three important observations can be made in regards to the downgradient sites:

- A consistently strong inverse association exists between depth and both arsenic and manganese;
- A strongly inverse association exists between pH and manganese and;
- Strongly positive associations exist between arsenic:cadmium, arsenic:lead, copper:manganese, copper:lead, and

TABLE 3-15
CONDENSATION OF KEY DATA FROM CORRELATION TABLES

PART A. UPGRADIENT (UPHILL) SITES

Independent Variables		Dependent Variables (log [HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
•Depth		-1.90	-1.80	-0.90	0.0	0.0	0.0	0.0
•pH		-0.90	-0.95	-0.95	-0.95	-1.85	0.0	-1.90
•log [HM]s	As	-	1.90	0.90	0.95	0.90	0.0	0.0
	Cd		-	0.95	0.95	0.95	0.0	2.70
	Cu			-	1.85	1.85	0.0	0.95
	Fe				-	0.95	0.90	0.90
	Mn					-	0.0	0.95
	Pb						-	0.0
	Zn							-

PART B. DOWNGRADIENT (DOWNHILL) SITES

Independent Variables		Dependent Variables (log [HM]s)						
		As	Cd	Cu	Fe	Mn	Pb	Zn
•Depth		-1.90	-0.95	0.0	-0.90	-1.80	-0.90	-0.95
•pH		0.95	0.0	1.00	-0.90	-1.85	-0.95	-0.95
•log [HM]s	As	-	2.80	0.0	1.80	0.85	2.75	1.90
	Cd		-	0.90	-0.05	-0.05	0.0	2.80
	Cu			-	-0.90	1.90	1.90	1.85
	Fe				-	0.95	0.95	-1.90
	Mn					-	1.00	0.95
	Pb						-	0.90
	Zn							-

copper:zinc pairs, and strongly inverse association exists between the iron:zinc pair.

These observations can be summarized:

- Arsenic tends to concentrate in the upper horizon(s) of a given soil profile:
- Zinc and manganese solubilities increase considerably as pH decreases; and
- Elevated levels of zinc generally indicates elevated levels of cadmium, arsenic, copper and possibly lead, while elevated levels of copper are commonly associated with elevated levels of iron, manganese and lead.

3.7.3 Evaluation of Contamination

The extent and severity of heavy metals contamination, as well as probable sources, were evaluated in a preliminary manner by inspecting Tables 3-12 through 3-15:

- Heavy metals contamination of soils occurs throughout the demarcated study area, and is particularly intense within the Silver Bow Creek and upper Clark Fork River floodplains (relative to the irrigated terrace sites);

- The floodplain sites A1 and A9 probably contribute dissolved metals to the shallow ground-water system, as seasonal water table levels are within or above those soil horizons containing elevated levels of plant-available heavy metals;
- Except possibly for site A13, heavy metals contamination of the terrace/alluvial fan sites is limited generally to the upper 18-24 inches of the soil profile, while expected geochemical (background) levels occur beneath the zone of contamination. Thus, ground-water contamination due to heavy metal leaching from these topographically elevated sites does not seem very likely; and
- Although vegetation growing on contaminated sites are accumulating elevated levels of metals (especially zinc), the concentrations are generally in the range that is non-toxic to livestock--unless such materials constitute their sole source of forage.

DRAFT

4.0 CONCLUSIONS

4.1 STUDY CONCERNS

The Phase One (Reconnaissance) objectives have been met. Strong circumstantial evidence has been provided to support the hypothesis that waterborne heavy metal contaminants, originating from upstream mining/mineral processing activities, have adversely affected agricultural activities within the study area.

Inspection of Table 3-12 indicates a strong contamination (heavy metal) gradient that decreases in concentration from Thurmond's floodplain site (A11) near Butte to Spangler's site A7, which probably received irrigation waters from the Watson Ditch (in turn connected to Silver Bow Creek). Similar observations are made for the Peterson sites, located adjacent to the Yellow Ditch. A second concentration gradient is observed for the Forsen-Dutton sites, wherein the former received contaminated waters from the E. Valiton Ditch, while the latter has received contaminated materials (mill tailings) from the Butte and Anaconda operations.

Deposition of heavy metals, and increasing acidity resulting from pyrite mineral oxidation, has been sufficiently severe--in some cases--to prevent vegetative growth. These conditions are particularly evident at the following sites: Konda's A3, Peterson's T13, Spangler's A7, and Forsen's A13. Given the depauperate nature, if not absence, of vegetation at the most severely affected

sites, these areas probably represent little danger to livestock; the exceptions to this assessment are heavy metal-tolerant plants growing along the margin of such denuded areas and potential off-site transport by wind and water erosion to adjacent, largely unaffected lands utilized routinely by livestock. However, at several of the less visibly affected sites (e.g. Thurmond's A11, Dutton's A9), cause for concern exists for the ingestion of heavy metals-contaminated soils by livestock during grazing, or from soil particles adhering to the harvested forage/hay.

However, the rural nature and remoteness of most of these affected sites limits the risk to humans via direct contact or ingestion of metals. Respiratory protection from dust generated during any remedial operations (e.g., deep plowing/liming) seems prudent.

4.2 ADDITIONAL CONCERNS

Seven concerns developed during the literature review (Section 1.1) and the RI:

(1) Given the available data, whether the areal extent and severity of heavy metals contamination of agricultural lands has abated over time cannot be determined definitively. The persistence of heavy metals in soils is such that lands historically affected probably still are burdened to varying degrees (depending on a host of physicochemical and biological factors which vary from one trace element to another, and from one soil type to

another). Furthermore, the field observations were used to "calibrate" additional interpretation of aerial photography for the study area; results of these efforts support the original estimate of approximately 5400 acres of clearly affected lands within the three counties of interest. If more subtle vegetative productivity (yield reduction) effects are included, the above estimate could increase by several-fold, possibly to 18,600 acres within the three-county study area (Schafer 1985).

(2) The data tables in Section 3.0 indicate sufficient time has passed since deposition that the more mobile elements (particularly zinc) have begun to concentrate at lower depths in the soil profile; thus, contamination severity has lessened for these elements, but not for those which tend to remain near the surface (e.g., copper, lead).

(3) As discussed previously, the residual contaminants pose some concern to the terrestrial food chain (as plants growing on contaminated soils can exhibit elevated metals levels), while a minimal threat to human health and welfare appears evident.

(4) Contamination by waterborne and airborne trace elements probably has occurred at several of the Peterson sites, as judged by comparison to certain soils data collected by Tetra Tech (1985b). Various untilled and tilled soils were sampled along their Crackerville transect during late September-early October, 1985; care was taken to avoid sampling near irrigation ditch

systems (Schmidt 1986). One of these sample pairs, CT-4A and 4B, was located within one-half mile east to east-northeast of the RI sample pairs T16:17 and T14:15. Acid-extractable heavy metal data for the Tetra Tech pair are shown in Table 4-1. The RI data (see Table 3-4) were averaged, and the respective means divided by two to approximate the 0-10 in. conditions sampled by Tetra Tech. Inspection of Part B of Table 4-1 indicates generally lower heavy metal levels at the CT-4B (alfalfa) site than at the Peterson sites, especially for lead. The apparent difference in respective metals concentrations is probably due in part to the historic use of contaminated irrigation water. However, the arsenic and copper concentrations at the CT-4A (untilled) site average at least 2.4 times the respective levels occurring at Peterson's. Unless it can be demonstrated that tillage or metals uptake by crops can approximately halve the accumulation of these metals over time, the only other probable source is from particulate airborne deposition.

(5) Airborne heavy metal contamination may have occurred also at the Spangler sites. Studies performed within the Deer Lodge Valley indicate that total levels of arsenic, cadmium, copper, and zinc in surface (0-6 in.) soils and associated plants sampled at distances up to 10 mi radius of the Washoe Smelter's main stack often exceeded their respective biogeochemical background levels. This observation must be tempered by the fact that areal magnitude of contamination varies from one element to another, while particulate deposition patterns for the above

TABLE 4-1
COMPARISON OF PETERSON SITE DATA WITH
TETRA TECH CRACKERVILLE TRANSECT DATA

PART A. CRACKERVILLE TRANSECT (SOILS) DATA

Site Name	Depth Sampled(in.)	Analysis Type	Elements (mg/kg) As	Cd	Cu	Fe	Mn	Pb	Zn
Untilled, CT-4A	0-2	Total (acid ext.)	430	8.7	500	16,900	406	241	244
	2-10	Total (acid ext.)	100	3.2	115	14,800	736	45	126
Tilled, CT-4B	0-2	Total (acid ext.)	102	3.3	132	14,200	470	51	117
	2-10	Total (acid ext.)	89	3.1	138	13,700	446	53	101

PART B. STATISTICAL COMPARISONS[a]

Data Source	Depth (in.)	As	Cd	Cu	Fe	Mn	Pb	Zn
MultiTech	0-5.25 ave.	188±58	7.1±0.8	317±74	23,075±10,009	682±291	157±54	264±79
	0-10 ave. (adj.)	94±29	3.6±0.4	158±37	11,538±5,004	341±146	78±27	132±40
CT-4B	0-10 ave.	96±9	3.2±0.1	135±4	13,950±354	458±17	51±1	109±11
CT-4A	0-10 ave.	265±233	6.0±3.9	308±272	15,850±1485	571±233	143±139	185±83
CT-4B/M	0-10 ave.	1.02	0.89	0.85	1.21	1.34	0.65	0.83
CT-4A/M	0-10 ave.	2.82	1.67	1.95	1.37	1.67	1.83	1.40

Note: a)Assumes zero concentration for each of these elements in the 5-10 in. soil depth at Peterson's. As this assumption is not realistic, the quotients would be smaller (for both CT-4B ÷M and CT-4A÷M) than as given. However, such adjustments do not change the conclusions that Peterson's sites have been affected by airborne a nd waterborne heavy metal contamination.

elements in surface soils varies non-uniformly with distance and direction from the smelter (MultiTech and Native Plants 1984). Similarly, the marginally elevated levels of total arsenic and cadmium measured at Konda's A1 and Thurmond's A10 (upgradient) sites may be due to stack emissions from the Colorado and Montana Smelter and/or Butte Reduction Works. Both of these operations were located adjacent to Silver Bow Creek and had relatively short stacks, wherein the plumes (containing the particularly volatile arsenic and cadmium) would be constrained topographically by the Silver Bow Creek channel and adjacent foothills.

(6) Finally, the best case for waterborne contamination is found at Forsen's site A13. As shown in Parts A and B of Table 4-2, acid extractable heavy metals at the Tetra Tech (1985a) sites are generally within their respective geochemical background limits; the one clear exception to this assessment is total zinc levels present within the upper 10 in. of soil at site VT6B. To further test the probable absence of significant smelter deposition effects, data from these two sites were pooled, log-normalized and compared (via Student's two-tailed t-test) against similarly treated data from Tetra Tech's background sites BG-4A and BG-4B (Schmidt 1986). Heavy metals and pH information for these latter sites are shown in Part C of Table 4-2.

The null hypothesis (H_o) of no significant difference (α=0.05) in total heavy metals contents between the Deer Lodge and

TABLE 4-2
COMPARISON OF RELEVANT VALLEY TRANSECT DATA BY TETRA TECH WITH THAT GATHERED AT FORSEN'S SITE A13[a]

PART A. TETRA TECH'S UNTILLED SITE VT-6A

Depth Sampled(in.)	Analysis Type	Elements (mg/kg, air-dried) As	Cd	Cu	Fe	Mn	Pb	Zn	pH
0-2	Total (acid extractable)	12	0.9	62	9,300	368	22	68	--
	Plant Available (DTPA ext.)	N.G.[b]	0.5	14	17	16	5	9.99	7
2-10	Total (acid extractable)	18	0.8	46	10,100	422	18	60.5	--
	Plant Available (DTPA ext.)	N.G.	0.3	11	13	11	3	5.5	7.4
10-24	Total (acid extractable)	<2.3	0.4	19	9,200	205	8	32	--
	Plant Available (DTPA ext.)	N.G.	0.05	2	5	3	0.6	0.85	8.0

PART B. TETRA TECH'S TILLED SITE VT-6B

Depth Sampled(in.)	Analysis Type	Elements (mg/kg, air-dried) As	Cd	Cu	Fe	Mn	Pb	Zn	pH
0-2	Total (acid extractable)	8.6	1.1	71	10,600	447	19	189	--
	Plant Available (DTPA ext.)	N.G.	0.4	18	6	11	2	32	7.8
2-10	Total (acid extractable)	11	0.9	62	10,200	415	16	169	--
	Plant Available (DTPA ext.)	N.G.	0.36	14	6	6	1.7	29	8.0
10-24	Total (acid extractable)	<2.3	<0.4	14	9,200	205	6	33	--
	Plant Available (DTPA ext.)	N.G.	0.03	1.5	3	2	0.4	1.8	8.1

TABLE 4-2
COMPARISON OF RELEVANT VALLEY TRANSECT DATA BY TETRA TECH WITH THAT GATHERED AT FORSEN'S SITE A13[a]
(Continued)

PART C. TETRA TECH'S TOWNSEND AREA (BACKGROUND) SITES

Site Name	Depth Sampled(in.)	Analysis Type	Elements (mg/kg, air-dried) As	Cd	Cu	Fe	Mn	Pb	Zn	pH
Untilled, BG-4A	0-2	Total (acid ext.)	3.4	1.4	21	18,600	625	55	95	--
		Plant Available (DTPA ext.)	N.G.[b]	0.3	0	<17.6	13	1	2	6
	2-10	Total (acid ext.)	3.2	0.4	17	18,631	532	18	66	--
		Plant Available (DTPA ext.)	N.G.	0.0	1	3	9	1	0	7.4
	10-25	Total (acid ext.)	5.2	<0.4	14	18,090	401	15	56	--
		Plant Available (DTPA ext.)	N.G.	0.01	1	5	6	1	1	7.7
Tilled, BG-4B	0-2	Total (acid ext.)	5.7	0.8	16	19,106	572	30	80	--
		Plant Available (DTPA ext.)	N.G.	0.1	0	<17.6	5	0	1	6.5
	2-10	Total (acid ext.)	4.7	<0.4	18	21,250	579	22	74	--
		Plant Available (DTPA ext.)	N.G.	0.0	0	<17.6	1	0	1	6.5
	10-25	Total (acid ext.)	3.6	0.5	17	19,796	473	<1.6	68	--
		Plant Available (DTPA ext.)	N.G.	<0.01	1	2	5	0	0	7.5

TABLE 4-2
COMPARISON OF RELEVANT VALLEY TRANSECT DATA BY TETRA TECH WITH THAT GATHERED AT FORSEN'S SITE A13[a]
(Continued)

PART D. RI SITE A13

Depth Sampled(in.)	Analysis Type	Elements (mg/kg, air-dried)[c] As	Cd	Cu	Fe	Mn	Pb	Zn	pH[c]
"0-4" (n=4)	Total (acid extractable)	454	14.8	2445	19,325	590	260	564	--
	Plant Available (DTPA ext.)	29.3	1.03	657.5	1.53	167	1.11	154.5	4.46
3-8 (n=2)	Total (acid extractable)	173	6.76	1615	16,500	578	101.1	402	--
	Plant Available (NH_4OAc ext.)	15.8	0.812	509	0.32	96.8	0.848	96.0	4.79
8-18 (n=1)	Total (acid extractable)	34.4	0.980	148	22,300	618	34.5	223	--
	Plant Available (NH_4OA_c)	2.33	0.180	6.94	1.14	2.48	<0.262	16.6	6.42
18-38 (n=1)	Total (acid extractable)	18.6	0.545	75.7	19,500	421	24.2	75.2	--
	Plant Available (DTPA ext.)	<0.687	0.044	12.5	2.38	2.98	0.310	5.48	7.93

[a] The Valley Transect sites are located approximately 1-1/4 miles north-northwest of the Forsen sites; the Tetra Tech background sites are located approximately 11 miles northwest of Townsend, Montana.
[b] N.G. = Not given (not reported).
[c] Presents only arithmetic means.

Townsend site pairs was accepted only for the cases of arsenic and zinc. Therefore, the Valley Transect pair was accepted as being a "control" site for these two elements only. No explanation is offered immediately for the surface zinc contamination at site VT6B. The background zinc levels at untilled site VT6A seem to rule out atmospheric deposition, while use of contaminated irrigation water would expectedly result in elevated levels of a number of elements, not just zinc. Regardless, Students' two-tailed t-test was performed as above using the VT site data and Forsen's site A13 data; the A13 data utilized are presented in Part D of Table 4-2.

The H_o was rejected at α=0.05 for all heavy metals but zinc, as well as for pH; the H_o could be rejected for the latter two parameters if α=0.10. Therefore, it is not unreasonable to conclude that Forsen's elevated metals are largely due to waterborne contamination.

(7) The RI study analyses included certain soil and plant measurements useful in evaluating alternative soil treatment and crop management practices during the Feasibility Studies. However, as the primary objective of this RI was assessing potential heavy metals contamination, the list of reclamation-related parameters tested for was by no means exhaustive. These possible deficiencies are addressed in the following recommendations section.

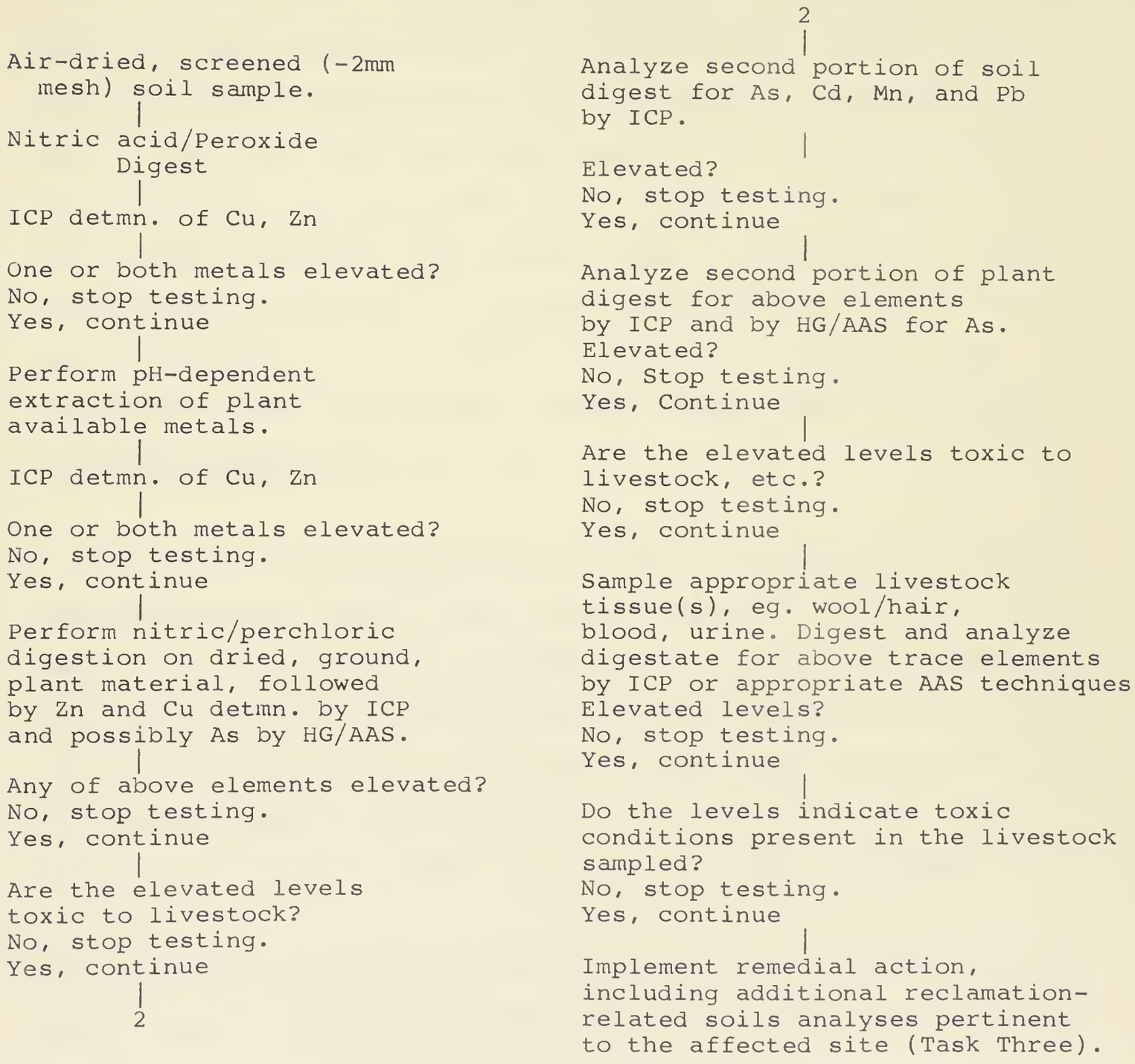
4.3 RECOMMENDATIONS

The present Agriculture study results indicate that irrigated agricultural lands have been contaminated through use of waters taken from Silver Bow Creek or from the Upper Clark Fork River, or by exposure to mill tailings-contaminated floodplain soils. Based on the results of the SBC Agriculture RI, a three-tasked approach is recommended for follow-on work. The application of the analytical screening approach in Figure 4-1 will result in improved demarcation of the contamination's areal extent, refined assessment of the severity of contamination, and evaluation of potential food-chain (metals accumulation) effects. Such efforts will be accomplished in a cost-effective manner, as sampling costs will be minimized, while analytical/data interpretation costs will be incurred only if they can be justified.

4.3.1 Task One

In Task One, soils and plant sampling would continue at those irrigated agricultural sites where waterborne heavy metal contamination is either known or suspected. The published results of the present SBC Agriculture RI (Phase One - Reconnaissance) efforts will probably stimulate the interest and concern of other agricultural landowners within the RI area. Consequently, landowner contacts are expected to be the chief source for sampling sites. Concurrent with soil/plant sampling, above-ground biomass production (clipping plot) studies would be performed.

FIGURE 4-1
RECOMMENDED ANALYTICAL SCREENING APPROACH FOR CONCLUDING
THE AGRICULTURAL RI


Air-dried, screened (-2mm mesh) soil sample.
Nitric acid/Peroxide Digest
ICP detmn. of Cu, Zn
One or both metals elevated?
No, stop testing.
Yes, continue
Perform pH-dependent extraction of plant available metals.
ICP detmn. of Cu, Zn
One or both metals elevated?
No, stop testing.
Yes, continue
Perform nitric/perchloric digestion on dried, ground, plant material, followed by Zn and Cu detmn. by ICP and possibly As by HG/AAS.
Any of above elements elevated?
No, stop testing.
Yes, continue
Are the elevated levels toxic to livestock?
No, stop testing.
Yes, continue
2
2
Analyze second portion of soil digest for As, Cd, Mn, and Pb by ICP.
Elevated?
No, stop testing.
Yes, continue
Analyze second portion of plant digest for above elements by ICP and by HG/AAS for As.
Elevated?
No, Stop testing.
Yes, Continue
Are the elevated levels toxic to livestock, etc.?
No, stop testing.
Yes, continue
Sample appropriate livestock tissue(s), eg. wool/hair, blood, urine. Digest and analyze digestate for above trace elements by ICP or appropriate AAS techniques
Elevated levels?
No, stop testing.
Yes, continue
Do the levels indicate toxic conditions present in the livestock sampled?
No, stop testing.
Yes, continue
Implement remedial action, including additional reclamation-related soils analyses pertinent to the affected site (Task Three).

Plant and soil sampling, plus clipping plot studies, at fields reputedly contaminated would be accomplished by properly trained seasonal technicians. Composite, representative samples of the upper six (and possibly twelve) inches of each profile would be acquired using an Oakfield-type tube sampler, as described in the SBC RI Work Plan (MultiTech and Stiller and Associates 1984a). Plant materials would be gathered as done in the current study's agricultural sampling. The samples would be processed by a sample bank/contract laboratory as described in pertinent sections of 2.0 of this document. Site-specific production estimates would be acquired via use of Methods 604 and 605, as described in the National Range Handbook (USDA SCS 1976).

An impact severity classification system would be created through field observation data; heavy metal levels (in soils and plant materials) statistically correlated with yield figures; "climatologically averaged" biomass production values taken from SCS range site guides; and clipping plot studies performed at the Tetra Tech geochemical control sites located near Townsend. The approved system would then be used to create an impact assessment map.

The recommended analytical screening process is presented in the left column of Figure 4-1. The task results would be threefold:

- Verification of the spatial extent of contaminated lands (possibly as far downstream as the Milltown Reservoir);

- Establishment of an impact severity classification scheme (i.e. one ranging from 100 percent yield reduction to subtle, but measurable, yield reductions); and

- Preparation of a preliminary map demarcating these impact units, which overlays a suitably scaled (e.g., 1:24,000) orthophotoquadrangle base map.

4.3.2 Task Two

In Task Two, the potential for food chain accumulation of metals would be evaluated at sites representing each of the above impact-severity mapping units. The technical staff would determine, from Task One data analysis and field verification, the reference sites to be used in the foodchain studies. The recommended sites would be approved by the MDHES/USEPA.

The recommended laboratory procedures are shown in the right column of Figure 4-1; note that such efforts would utilize the site-specific soil and plant digestates produced by the Task One efforts, as well as livestock tissue sampling (if it can be justified). Analyses of other soil parameters (e.g., organic matter content, liming requirements) would be performed as judged necessary.

4.3.3 Task Three

The third task would involve pilot-scale reclamation studies. Reclamation plots would be established at selected sites (identified in Task Two) to test the effectiveness of growth medium changes (e.g., liming, soil amendments, fertilizer rates) and use of selected crop/forage species. The central objectives of this task are twofold:

- Improved productivity on the affected lands; while
- Prevention of heavy metals accumulation in the terrestrial food chain and simultaneous reduction (if not elimination) of off-site impacts (e.g., due to wind and/or water erosion).

The on-going efforts by the Deer Lodge Valley Conservation District *et al*. at their reclamation study plots located on the Spangler ranch may serve as a good model for implementing this task (Dodge 1984). Data currently being generated at the Spangler sites, as well as literature review information, would be utilized by the technical staff to develop and implement a series of reclamation plot studies. The resulting information would be compiled and reviewed, allowing effective evaluation of the relative feasibility of various remedial technologies during the FS process.

Data generated at the Spangler plots (e.g., seed germination studies) to date are encouraging. If they are continued, and expanded geographically, they will support any site remediation efforts on degraded agricultural lands.

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DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT I

MEMO TO MIKE RUBICH FROM JAY CORNISH
DECEMBER 14, 1984

STATUS REPORT REGARDING
THE AGRICULTURAL SYSTEMS INVESTIGATION

MultiTech

In summary, the first task efforts are well underway. Several cases of documented (zinc) phytotoxicity and (copper-arsenic related) livestock losses have been identified. However, these problems do not appear to be as prevalent as alluded to in the Work Plan (p. 2-75). Three hypotheses are offered: 1) such heavy metal contamination is widespread, but only under certain sets of environmental conditions does it become severe enough to be recognized; 2) moderately-to-severely-affected landowners may not be willing to admit such problems exist, for fear of economic devaluation of their property(ies); or 3) the agricultural community recognizes and simply avoids the "hot spots" (e.g., "tailings easement" areas within the Clark Fork River floodplain; Jim Windorski, personal communication).

Given the information collected to date, the second task efforts should be organized as follows. First, sampling and analysis of soils, crops and livestock should occur at those landowner sites where such problems have been confirmed or are highly probable (see Table 1). Such efforts could be expanded to include those sites not sampled to date, but where such problems are suspected. These efforts are not redundant, as very little (if any) of the data satisfies "Level B" QA/QC criteria (USEPA 1984b). Therefore, this information may not be acceptable for inclusion in an endangerment assessment. Secondly, the "Area V" transect sampling of tailings deposits (p. 2-41) should be extended laterally into irrigated farmlands. This effort will provide useful cross-sectional "views" of heavy metal migration from, and possibly back to, the Clark Fork River.

Further details on methods used, information gathered and evaluated, plus recommendations for continuing these investigations are discussed in the following text.

TABLE 1.--SUMMARY OF TELEPHONE INTERVIEW FINDINGS[a]

PART A. HEAVY METAL PHYTOTOXICITY[b]

Confirmed	Highly Probable (Zn-Cu-As)	Suspected (Zn-Cu-As)
G. Seitz (Zn, H)	J. Archer (G)	B. Craddock (H)
	H. Fergeson (H)	W. Konda (H)
	S/H. Kellicut (H)	D. Ueland (H)
	H. Spangler (C)	W. Peterson (H)
		D. Beck (H)
		K. Edge (H)
		J. Hoag, FFA Farm (H)
		D. Forsen (H)
		H. Long (H)
		B. Murphy (H)
		D. Hewitt (Opportunity Community Pasture), (H)
		G. Tammen (H)

PART B. LIVESTOCK LOSSES TO HEAVY METAL POISONING

Confirmed	Highly Probable	Suspected
J. Archer (Cu, sheep)	--	H. Fergeson (cattle)
G. Seitz (As, cattle)		H. Long (cattle

PART C. LIVESTOCK FLUORIDOSIS (MORBIDITY/MORTALITY)

Past Problems	Present-Suspected Problems
B. Arms (cattle, horses)	W. Konda (cattle)
J. Archer (horse)	D. Ueland (cattle)
H. Spangler (cattle)	
Dutton Ranch (cattle)	

Notes: a) See Appendix A for supporting details.

b) Crop codes as follows: C = small grains (e.g., barley); G = garden produce; H = wild or cultivated haylands.

METHODOLOGY

Attempts were made, throughout the first week in December, to contact by phone those individuals listed in Appendix Table 4.5-5. The interview protocol was that shown in Figure 2-7. The previously compiled data base regarding hardrock mine/smelter effluent effects on agricultural production was expanded. This was accomplished via literature review and discussions with Mrs. Alice Finnegan, Director of the Tri-County Historical Society's archives in Anaconda.
To date, the references used to evaluate the data acquired are as follows:

- Soils, Harrington et al. 1983, Schafer 1979;
- Phytotoxicity, Rice and Ray 1984;
- Livestock, Clarke et al. 1981, Puls 1981; and
- Human health, a confidential study prepared by CH_2M Hill.

RESULTS

Telephone Interviews

Of the 55 landowners listed in Appendix Table 4.5-5, only 43 were actually interviewed. In most of the cases of "non-contact," the particular individual could not be reached despite repeated calling (including after 5:00 p.m.). In the remaining instances, the appropriate number could not be acquired via the Butte City Directory or from directory assistance. The pertinent results are shown in Table 1.A more detailed summary of the findings can be found in Appendix A. Of particular interest are the cases of confirmed occurrences of zinc phytotoxicity- arsenic poisoning of cattle at the Seitz residence, and copper

poisoning of a buck at the Archer residence. Furthermore, there is a high probability of As-Cu-Zn phytotoxicity at four other garden, hayland, or small grain production sites. In most of these cases various mitigating measures (i.e., deep tillage, liming and manure application) were applied, with varying degrees of success. Thus, the RC&D/SCS/Extension Service test plot studies being implemented at the Spangler residence will be followed closely, as their results should contribute significantly to (future) evaluation of cost-effective remedial action(s). An overview of these studies is presented in Appendix B (Ted Dodge, personal communication).

Elevated levels of As and/or Pb have been observed in blood or other tissues taken from horses living in the Butte-Anaconda area. Two veterinarians practicing in Deer Lodge were contacted regarding autopsies of livestock affected presumably by heavy metals. To their knowledge, confirmed diagnosis of such poisoning has not occurred for over 15 years, (Drs. Heaton and Murphy, personal communications). However, the fatal poisoning of cattle or sheep documented above show that such events do occur every so often. Consequently, additional testing of the "confirmed" and "highly probable" cases (Table 1) is justifiable. Finally, some livestock herds may be stressed presently by fluoride emissions arising largely from the Stauffer Chemical operations. It is suggested that any vegetation samples taken during the Task 2 efforts be analyzed for fluoride content. In this manner, the potentially confounding effects on the agricultural systems heavy metal investigations can be evaluated effectively.

Literature Review

Efforts were made to supplement the discussions contained in Section 4.4.2 of the Work Plan. In regard to tailings deposition on floodplains, three articles were reviewed. Bateman and Wells (1917) studied the response of riparian vegetation, and one alfalfa-clover field, to tailings deposition in October 1914. The flooding appeared to be "recent" and extended from Silver Bow Creek to some distance downstream of Warm Springs Creek. Chemical analyses of the tailings and vegetation indicated willow mortality due to copper, zinc, arsenic, and "free sulfuric acid" (p. 818). However, other species such as Dasiophora fruticosa (probably Potentilla sp.), "wild rose" and an Equisetum (horsetail) species were generally resistant to tailings innundation. These plants often thrived in spite of, "large amounts of iron and sulfate and smaller amounts of zinc, cadmium, thallium, with traces of lead," (p. 815). Smaller amounts of selenium, tellurium, manganese, magnesium, antimony, and aluminum were also observed. In regards to the "deserted farm land" (p. 814), alfalfa was present only, "in the slightly elevated spots of the field while no grass at all was found at this place." The clover, "appeared to have been suddenly killed while in full bloom" (p. 814).

Peter Rice and Gary Ray (1984) studied, among other things, the severity and extent of heavy metals contamination present at the USNPS Grant-Kohrs Ranch. Extensive sampling of the upper 25 cm. of the soil profile indicated that total As, Cu, and Cd levels are one to two orders of magnitude greater than concentrations in similar soils from areas not exposed to, "major sources of anthropogenic pollution" (p. 64). The severity of contamination generally decreased as one moved away from and above the river. The major exception were those

topographically elevated fields crossed with irrigation ditches and subsequently affected by occasional flooding. Acute phytotoxicity is evident at the "slickens" located in the riparian zone. There, total Cu, As, and Cd levels averaged 1630 ppm, 176 ppm, and 5.0 ppm, respectively. It is probable that subtle chronic phytotoxicity, due particularly to copper, is also occurring on portions of the ranch. There does not appear to be a risk of acute metal poisoning of livestock on the property. However, Rice and Ray recommended fencing and grazing practices that would exclude livestock from areas with high soil and plant heavy metal concentrations, especially in the spring and fall. They also recommended "dilution feeding" whereby replacement hay obtained from "non-contaminated areas" would--upon feeding to the animals--reduce the dosage consumed by grazing on pasture grown on the Ranch (p. 68).

The third article deals with heavy metal enrichment of Oker River floodplain sediments in Germany, (Baumann 1984). This river flows from the Harz Mountains and carries mine-mill-smelter wastes generated by centuries of extraction and processing of silver-bearing Pb-Zn-Cu sulfide ores. "Extreme enrichment" of Pb and Zn and "medium to major" enrichment of Cu, in contrast to the "minor enrichment" of Co and Ni in the floodplain sediments can be traced at least 200 km downstream of the effluent sources. Although mineral processing is viewed as the major contributor, such discharges have been, "recently augmented by contributions from domestic and industrial sewage water..." (p. 590). The impacts on river valley ecosystems have been known for nearly two centuries. The Innerste River also drains portions of the old mine-smelter district. C. F. W. Meyer observed (ca 1822) stunted growth of herbs and corn cultivated on alluvial soils in the Innerste Valley, "a phenomenon which is still noticeable at present time," (p. 590). Meyer also noted that horses and cattle grazing in the upper

portions of the Valley often died of metal poisoning. "Unusually frequent diseases and sudden dying of poultry in the Innerste Valley were caused by metalliferous sediments" (p. 590).

Mrs. Finnegan informed me that Mr. Tom Radonich (AMC) will deliver archival materials pertaining, "to the history of Opportunity, including the "smoke case", one of these days," (personal communication). Many boxes of company records are stored currently in the old City Hall. Unfortunately, they have not been catalogued or organized by subject matter; subsequently, location of documents pertinent to this investigation will probably be difficult to find. However, the Montana State Historical Society is currently archiving, "approximately 800 cubic feet," of ACM/AMC files (Ms. Ellie Arguimbau, personal communication). Ms. Arguimbau is currently searching the materials for internal reports, etc., regarding smelter-agriculture conflicts. I will peruse any such documents discovered by her, and browse the relevant portions of the Bliss vs. Anaconda Copper Company transcripts, while in Helena on December 17, 1984.

Acquisition and review of pertinent literature continues; currently the two treatises being studied are those by Martin and Coughtrey (1982) and by Nriagu (1979). Important findings will be passed along via the monthly management status reports.

RECOMMENDATIONS

Phase I, Task One

Presently, there appears to be at least five landowners who have lost livestock and/or observed phytotoxicity as a result of heavy metal contamination (Table 1). The following efforts should be completed prior to the end of December:

- Inspection of aerial photography plus geoedaphic/topographic data pertinent to the above lands. This will include office visits and/or telephone conversations with Ted Dodge, Huey Long, Bill Schafer, Dave Streufert, and Bob Tribelhorn.
- Visit at least several of the affected landowners, time- and weather-permitting. In such cases, the protocols shown in Figure 2-8 of the Work Plan will be followed.

The five landowners will be interviewed prior to formal completion of Task One. This task should be completed by late January 1985.

Phase I, Task Two

Reconnaissance level sampling of soils, plant materials and livestock tissues will occur at those sites where it can be justified (i.e., the above five landowners and at several as yet unidentified "control" sites). Sampling methodologies will follow those proposed for Phase II (pp. 2-90 through 2-101 in the Work Plan). A tentative addition is clip-plot studies. The aerial biomass ("yield") data can be compared against certain physiochemical data (e.g., soil-extractable Zn); the search for inverse relationships between production and potential contaminants can then occur. The "additional parameters" mentioned

on p. 2-69 should include the following: EC; extractable N-P-K; extractable As, Cu, Zn; organic matter, pH, sulfate ion, and textural analysis. All sampling and analytical techniques will follow "Level B" Quality Control/Quality Assurance (QC/QA) criteria. The above efforts would be scheduled for late April-early May 1985. This will allow adequate time for deciding whether or not to implement Phase II activities by mid-June, in accordance with the Work Plan (p. 2-96).

A second approach is to extend the "Area V" tailings-transects (p. 2-41) laterally into irrigated farmlands, (Bill Schafer, personal communication). Depth-integrated, composite, sampling of tailings and soils could be implemented as shown in Figure 1. The sampling and analytical methodologies would be similar to those discussed above. The subsequent statistical-graphical evaluations will provide useful information on heavy metal migration from, and possibly back to, the Clark Fork River. These efforts would be scheduled also for Spring of 1985.

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APPENDIX A--PERTINENT FINDINGS RESULTING FROM THE TELEPHONE-RELATED INTERVIEWS

PART A. MILE-HIGH SOIL CONSERVATION DISTRICT (SILVER BOW COUNTY)

Landowner(s) Name(s)	Comments
Mr. Benton Arms	Doubts that heavy metals have affected his soils, crops or livestock. However, Stauffer Chemical veterinarians annually inspect his cattle for fluoridosis problems; he alledges past damage to both cattle and horses as a result of consuming fluoride-contaminated plant materials.
Mr. Bill Craddock	Has "patchy areas" where grass does not grow, and suspects smelter fallout; however, he has not tested soils or crops for heavy metal content. In regards to livestock, Stauffer has compensated him for cattle-related fluoridosis problems in the past. At his suggestion, his daughter (Mrs. Judy Archer) was contacted regarding garden soils analyses. The report form indicates 483 ppm total As, >10.0 ppm extractable Cu (extractant unknown), and >4.0 ppm extractable Zn (extractant unknown). However, it was stated that, "detrimental levels of copper and zinc were observed", and deep-plowing or liming was recommended. She has tried N-P fertilization and manure over the past 17 years, with mixed results. They have had one 4-year old buck (sheep) autopsied, with confirmed copper poisoning diagnosed, (i.e., "the liver was shot"). Previously, a horse was autopsied, with high fluoride observed in the bones.
Mr. Walter Konda	Overflow areas adjacent to Silver Bow Creek have problems with, "getting grass to grow" and he suspects copper poisoning. Soil analyses were performed "years back" but Mr. Konda cannot remember the details. Stauffer Chemical continues fluoride testing of his cattle.
Mrs. (Don) Ueland (12/3)	They have pasturelands with sufficient acidity that liming is required. However, she suspects fluoride contamination rather than heavy metals. Stauffer Chemical veterinarians annually test for fluoride content in their cattle.

APPENDIX A--PERTINENT FINDINGS RESULTING FROM THE TELEPHONE-RELATED INTERVIEWS (CONTINUED)

PART A. MILE-HIGH SOIL CONSERVATION DISTRICT (SILVER BOW COUNTY) (CONTINUED)

Landowner(s) Name(s)	Comments
Mr. Dan Ueland (12/5)	Mr. Ueland is nearly certain that smelter fallout has affected his lands. His soils are tested currently for pH, N-P-K, and "some metals". At present, he suspects cattle fluoridosis as a result of consuming contaminated forage; arsenic contamination may have been a problem, "15-20 years ago".
Mr. William Peterson	Remarked that his soil contamination problems, "are old ones." In the past, soils have been analyzed for heavy metals as follows: 22.16 ppm Cu; 21.7 ppm Zn; 24.74 ppm Fe; 19.56 ppm Mn, and 101.25 ppm As. Unfortunately, the exact sampling location is not clearly stated on the report form.

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES)

Landowner(s) Name(s)	Comments
Mr. Charles Beck	"Small problems occurred 30-40 years ago, but the metals have probably been leached out." He doubts that any sampling/analysis for heavy metals has been done (on his property) for at least 15 years.
Mr. Don Beck	Has property east of the CFR near Racetrack where "copper slimes" have caused problems with hay production in the past. However, he has never sampled his soils, crops, or livestock to check for heavy metal problems.
Mr. Melvin Beck	Although heavy metal problems are not evident on his property, he referred to "sterile lands" adjacent to the Prison Ditch. Furthermore, waters in the Westside Ditch," used to turn brown in the spring, causing the crops to turn yellow," but "were then OK afterwards."
Dutton Ranch	MSU has tested soils, crops, and livestock parts in years past in regards to litigation with the Garrison phosphate operations.

APPENDIX A--PERTINENT FINDINGS RESULTING FROM THE TELEPHONE-RELATED INTERVIEWS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Comments
Mr. Leonard Eliason	Remarked that contaminated bottomlands exist; his father, "sold ~40 acres to the ACM years ago." Mr. Eliason researched means of "clearing up the river" during the late 1950s through early 1960s. He thinks that his field notes may be around home, while other company records may be archived in Tuscon, Arizona.
Mr. Keith Edge	He has lands, "near the old ditch where nothing grows," despite liming and use of different grasses (e.g., wild rye, barley). Although he has never tested the soils, crops, or livestock, he thinks, "somebody tested down by the river," (Hydrometrics?).
Dr. Harry Fergeson	Despite his reticence it was learned that: he does have lands probably contaminated by heavy metals; has had, "at least 50 EPA jokers sampling," but does not remember their names, etc.; does possess chemical analyses of livestock tissues, but would not state the parameters and will not let the data be released for inspection. However, he is the past President of the American College of Veterinary Toxicology and would be willing to help implement the livestock investigations, "for a price."
FFA Farm, Powell County High School (Mr. Jim Hoag)	Mr. Hoag has not observed adverse effects on their native hay-pasture lands. The results of May '83 soils testing (MSU) included the following DTPA-extractable results: Cu 44.8 ppm; Fe, 30.7 ppm; Mn, 30.7 ppm; and Zn, 129.8 ppm. No livestock problems have resulted from consuming these plant materials.
Mr. Dick Forsen	Has ~300 acres of land (east of the CFR) that are not being cultivated; he presumes the problem has arisen from heavy metal accumulation as a result of irrigation over time. However, the area has begun to naturally revegetate over the past 18 years without the use of irrigation.
Mrs. (Orville) Fries	She said their property is OK, but remarked that the "ACM has waste ground within the Valiton tract." (Note: The plot book in Deer Lodge shows this land to be in the NE 1/4 of the NE 1/4 of Section 9, T6NR9W; to the Assessor's knowledge, this is the only land given such designation.)

APPENDIX A--PERTINENT FINDINGS RESULTING FROM THE TELEPHONE-RELATED INTERVIEWS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Comments
Mr. Rasmus Indreland	Mr. Indreland has researched the problem of lands contaminated (by heavy metals) as a result of using Clark Fork River water. He claims that flooding during the period 1912-1918 resulted in massive discharge(s) of tailings from the Washoe operations; somewhere between 15,000-20,000 acres of bottomland were subsequently contaminated with As-bearing wastes (~48 acres of which are on his property). Although cow manure and fertilizer mitigated much of the problem, it was very expensive to do so. The ACM Co. purchased 1/3 to 1/2 of such affected lands, and acquired "flowage easements up to the highwater mark on most of the rest at least as far as Deer Lodge." (Note: Mr. Jim Windorski has vouched for the existence of the tailings easements, but was not sure about the above details. The Assessor's office in Deer Lodge was not sure about any of the above matters.) Mr. Indreland has never had his soils, etc., tested for heavy metals as he, "knows that ACM land is poisoned."
Mr. Bud Jacobson	He doubts heavy metal problems exist currently on his lands. However, he recounted his father's (past) experience with horses dying of arsenic poisoning, especially during the fall. The presumed cause was heavy metal particulate accumulation, "sticking to the grass."
Mr. Allen P. Johnson	He has had, "no problems to speak of since the late 1950s;" he recalled times when he had to close the main diversion gate, when, "the water [in the Kohrs-Manning Ditch] looked like mud, after turning the smelter loose."
Mrs. (Bill) Johnson	They have several acres of land adjacent to the River that, "are under the ACM tax rolls." As the land has been affected adversely, they "have stayed away from it." The Johnsons have not tested this land for its heavy metal content.

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s) — Comments

Skip and Helen Kellicut

Their 16 acres of property lies in a strip east of the River and has been contaminated with Cu and Zn; being, "the highest copper and zinc-containing soils ever received at MSU." The SCS has recommended Garrison creeping foxtail, "but it has not done as well as the natural redtop." Mrs. Kellicut will search their files for the analytical results. USEPA personnel have sampled/analyzed several garden vegetables. The results are shown below (data in ppm):

Vegetable	As	Cu	Zn	Cd	Pb
Potatoes	ND	1.7 ± 0.34	3.0 ± 0.6	ND	ND
Lettuce	0.02 ± 0.004	0.21 ± 0.05	2.6 ± 0.52	ND	ND
Snow Peas	ND	1.0 ± 0.2	8.5 ± 1.7	ND	ND

(where ND = Not detected)

Their livestock eat the bottomland hay (during the growing season and into the fall); there has been no problems evident as a result of consuming these materials. The manure is then used to fertilize the garden.

Mr. Huey Long

"A small acreage" of contaminated land exists adjacent to an old irrigation ditch, as well as "slickens" in the bottomlands (on his property). These areas have not been tested for heavy metals, however. He has had livestock losses following feeding in the bottomlands, but the "animals were in rough shape upon arrival." Currently, he is considering butchering a "dry cow" and having certain tissues analyzed for heavy metal content. Mr. Long thinks that much of the metals present in the "wastelands" south of Deer Lodge are slowly leaching, "as the vegetative cover is good."

Mrs. (Bill) Murphy

They have problems with a field, "above the floodplain" but don't know what the cause is; they submit samples to MSU annually for fertilizer testing, but not for heavy metals. No problems are evident regarding cattle and horses eating the hay.

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Comments
Mr. Lars Olsen	Mr. Olsen runs cattle on both sides of the River, and has lands contaminated by tailings. However, he is totally opposed to any studies on his land.
Opportunity Community Pasture (Mr. Don Hewitt)	Mr. Hewitt knows of spots where vegetative growth, "isn't too good;" as no heavy metals sampling/analysis efforts are known to him, it is not clear whether this is part of the problem. However, he doesn't suspect heavy metal toxicoses in the cattle or horses.
Mrs. (Jack) Probert	Have some salinity-related cropping problems, but doubts any influence from heavy metals (although they have never tested for such).
Mrs. Audrey Ragsdale	Several acres of land on the "old farm" have been contaminated with tailings; she wasn't sure whether or not tailings are present on the active property. Her son is working, "with Bob Tribelhorn on a minor arsenic problem." (Note: Bob isn't sure that he has ever helped Scott on this matter, but will check with the field crew to see if they were involved or if any samples have been sent to MSU for analysis. Huey Long has mapped the soils of the area, but can't recall submitting any samples for heavy metal analyses).
Rock Creek Cattle Co. (Mr. Don Davis)	They have property adjacent to River which was flood irrigated "way back" in the past; although some vegetative cover exists, its growth "has been set back." He recalls soil analyses indicating high levels of Cu and Zn, but doubts he can find the data sheets.
Mr. Greg Seitz	He has lands wherein zinc phytotoxicity has been identified via soil analyses performed ~3 years ago; extractable Zn levels ranged from 7-246 ppm. The USEPA has sampled garden produce acquired from, "the hired man" but they have never received the analytical results. (Note: Jim Dunn recalls no phytotoxicity problems or likelihood of chronic human toxicity observed at the Marty Hunter property, directly east of Seitz's.)

APPENDIX A--PERTINENT FINDINGS RESULTING FROM THE TELEPHONE-RELATED INTERVIEWS (CONTINUED)

PART B. DEER LODGE VALLEY SOIL CONSERVATION DISTRICT (DEER LODGE AND POWELL COUNTIES) (CONTINUED)

Landowner(s) Name(s)	Comments
	Mr. Seitz also mentioned a derailment of a concentrate (railroad) car wherein a complete cleanup never occurred; rather, the area was fenced off. He is concerned about this, as the materials are mixing with adjacent spring water, forming "blue water" which may be toxic. He has lost 9 head of cattle wherein the MSU/Veterinary Laboratory analyses strongly indicate acute arsenic poisoning; Mr. Seitz will search his records for the laboratory data. He continues to lose cattle to what appears to be "grass tetany" (i.e., hypomagnesemia); however, this diagnosis needs to be confirmed from the liver and kidney analyses now being performed by the MSU/Veterinary Laboratory.
Mrs. Hazel Spangler	Mrs. Spangler has fields wherein the yield of barley is only one-half of that expected, and suspects heavy metal contamination, especially As. She has had no problems regarding cattle fluoridosis, "for over three years." (Note: preliminary soils mapping and limited soils testing has been done by Huey Long et al. Ted Dodge et al. have initiated test plot liming/revegetation studies focused on cost-effective approaches to reclaiming heavy metal-affected lands.)
Mr. Gerald Tammen	He has, "patches of ground where production is spotty," and suspects smelter fallout as being part of the problem. MSU has analyzed soil samples and reported heavy metal content as being, "just barely safe." The addition of manure was also recommended.

Note: a) The telephone log (interview) sheets are stored in project files at MultiTech.

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT II

MEMO TO MIKE RUBICH FROM JAY CORNISH
FEBRUARY 8, 1985

STATUS REPORT (II) REGARDING
THE AGRICULTURAL SYSTEMS INVESTIGATION

MultiTech

ATTACHMENT II

A Division of MSE, Inc.
P.O. Box 4078
Butte, MT 59702
(406)494-6319

Date: February 8, 1985

To: Mike Rubich

Thru: Robert Trout

Copies: Gordon Huddleston

From: Jay Cornish

Subject: Status Report (II) Regarding the Agricultural Systems Investigation

SUMMARY

This memorandum presents work accomplished towards completing Task One of the Phase I agricultural-related investigations. It includes a recommended list of 8 primary and 4 alternate sampling sites. Landowner site characteristics are presented in Table 1. Following MDHES approval, landowner visits will be implemented to document-stake actual sampling sites. Attempts will be made to complete these visits by the end of this month. In such case, limited core-drilling could occur in March, prior to encountering ground-thaw/site access problems. Otherwise, site conditions, crop phenology (sampling) requirements and necessary soil mapping activities could postpone sampling until early July. However, this would be the case regardless of scale-of-investigation, if crop material is to be concurrently sampled (as stated in the Work Plan).

METHODOLOGY

Intially, those individuals listed in the first (12/14/84) memo were re-contacted so as to validate their pertinence to this study. The objective was to eliminate from further consideration those landowners who are affected largely--if not solely-- by particulate fallout from the smelter stack. Subsequently, the original list (Table 1, Parts A and B, in the December memo) was revised. Further conversations with USDA/SCS personnel in Deer Lodge and Whitehall inspection of aerial photography and topographic maps, and review of county landowner records were completed also. The "new" list was prepared using three major criteria. These criteria are: perceived relevance to Work Plan objectives; apparent landowner willingness to participate in these studies; and availability of background data (e.g., crop-field management history) useful in evaluating the laboratory data. The three basic site types are as follows: those exhibiting surface accumulation of mill tailings; those or the Clark Fork River; or fields irrigated or subirrigated using either of these waters.

TABLE 1.--LANDOWNER SITES RECOMMENDED FOR AGRICULTURAL-RELATED SAMPLING. [a]

PART A. FIRST CHOICES

Landowner Name	Site Location/Map Code[b]	Comments
C. Benson	SE 1/4 33, T7NR9W/8	He owns hundreds of acres of land in Sections 16, 21, 28 and 33 which are probably affected by Valiton Ditch (contaminated) waters and/or mill tailings inundation. Also, a major livestock producer who allows some of his cattle to graze in the Clark Fork River bottomlands. He is very eager to cooperate with this study.
D. Forsen/Mrs. Frank Lovell.	NE 1/4 16, T7NR9W/9	Operations incorporate most of the old Prison Farm, which was severely affected by use of Valiton Ditch waters (for irrigation). They are very willing to cooperate with this study.
J. Hollenback	NW 1/4 36, TIONR11W/ Figure 2	Based upon phone description of his property, this would ba a good "control site".
S./H. Kellicut	NW 1/4 21 T6NR9W/4	Previous USEPA (garden produce) sampling, ongoing water quality sampling by Stiller et al. and description of problems with their subirrigated hay field make this an interesting "food chain" study site.
W. Konda	NW 1/4 16 T3NR9W/1	A good site as he is knowledgeable about long-term cropping history and is very willing to cooperate with the study. Stiller et al. are currently sampling near his property.
H. Long	NE 1/4 9 T6NR9W/7	Very knowledgeable regarding soils contamination by mill tailings problem. Very willing to cooperate with the study.
W. Peterson	SE 1/4 35 T4NR10W/3	The site was probably contaminated by tailings overflow, as well as heavy metal-laden waters, from the Yellow Ditch (which flowed from Silver Bow Creek).

Landowner Name	Site Location/Map Code[b]	Comments
H. Spangler	SW 1/4 25 T4NR10W or SE 1/4 36 T4NR10W/2A,B	The former site is being investigated by the Headwaters Resource Conversation and Development Office et al. The latter site has been exposed to mill tailings and irrigation water taken from Silver Bow Creek. She will be very cooperative.

PART B. SECOND CHOICES

Landowner Name	Site Location/Map Code	Comments
D. Beck	NE 1/4 16, T6NR9W/5	Very close to Kellicut's property.
K. Edge	SE 1/4 9, T6NR9W/6	Very close to Long's property.
H. Fergeson	NE 1/4 23, T4NR10W/4	He may be difficult to work with; "equivalent ground" owned by Spangler is right adjacent to his property.
FFA Farm Jim Hoag)	SE 1/4 16 T8NR9W/not shown in either figure.	Located approximately 2.5 miles N. of Deer Lodge; it would be a useful "contaminated" site, if one is needed north of town.

Notes: a) All phone logs and other supporting data are available for inspection at MultiTech. See Appendix A for further details regarding phone interviews/office visits.

b) See Figures 1 and 2 for sampling site locations. Sites are numbered in a "downstream" direction, starting west of Butte and proceeding northerly from there.

Finally, sites were located so as to evaluate the potential variability in tailings-irrigation water effects (on agricultural systems) as one travels downstream from Butte to Deer Lodge.

RESULTS

The important findings and conclusions from the personal and/or phone interviews are presented in Appendix A. Two key points should be noted:

- the "confirmed" cases of heavy metal phytotoxicity and livestock losses (i.e., the Seitz and Archer-Craddock properties) now appear to be affected largely by smelter particulate fallout. This assessment is probably true also for the Ueland, Tammen (and probably Hewitt) properties; and

- the remainder of the "highly probable" and "suspect" cases are more strongly viewed as being suitable sampling sites. Another major landowner, Mr. Cliff Benson, was identified as having a number of promising candidate sites.

In regards to soils mapping, the following information was discovered:

- the Deer Lodge SCS field office has preliminary soils maps for the Edge, Fergeson, Forsen/Lovell, Long and Peterson lands (of interest); the Beck, Benson and Kellicut properties have not been mapped, although small tracts could be done this spring (once staked), (Tony Rolfes, pers. comm.); and

- the Whitehall SCS field office has not mapped any lands along Silver Bow Creek. However, they will consider "test mapping" on a small tract owned by Walter Konda later this summer, (Don Strom, pers. comm.).

Based upon current mapping taxonomy, the tailings-inundated soils are classified as being a Typic Fluvaquent-Slicken complex (5). The other common floodplain mapping unit is designated as being Aquolls and Aquents, undifferentiated (4). Cursory descriptions of these two units are found in Appendix B. A number of soil mapping units, present on lower stream terraces, have probably been affected by heavy metal-contaminated irrigation waters. These units include Baggs (31), Varney-Anaconda complex (36) and Vastine (634). Profile description sheets are included also in Appendix B for the three published series; as Baggs is a tentative series, a cursory description only is found in the appendix (forthcoming).

RECOMMENDATIONS

The 8 "first priority" sites listed in Table 1 (Part A) should be sampled during the Task Two, Phase I efforts. A tentative "control" site has been identified in the Gold Creek area. Mr John Hollenback has fields irrigated using Gold Creek, and waters his cattle and horses from a spring. His properties are located away from the Clark Fork River and should be situated outside of the smelter's major "fallout zone" (i.e., 10-15 miles radius of the Washoe Stack).

If time and budget allow, the "lower priority" sites (Table 1, Part B) could be sampled also. Most of these sites are noted in Figure 1, using Table 1 as the legend. This over-sized sheet is attached to this memorandum. The approximate boundaries of Mr. Hollenback's property are shown in Figure 2. The previously recommended scheduling of Phase 1, Task Two, sampling in late April-early May will exclude (probably) any crop sampling. Aerial biomass production will be minimal, with no seed heads being available for the proposed clip-plot studies. However, two options are evident:

A. to initiate soil sampling prior to the "spring thaw", subsequently resampling crop materials at the appropriate stage of development (see pp. 2-98, 2-99 in the Work Plan); or

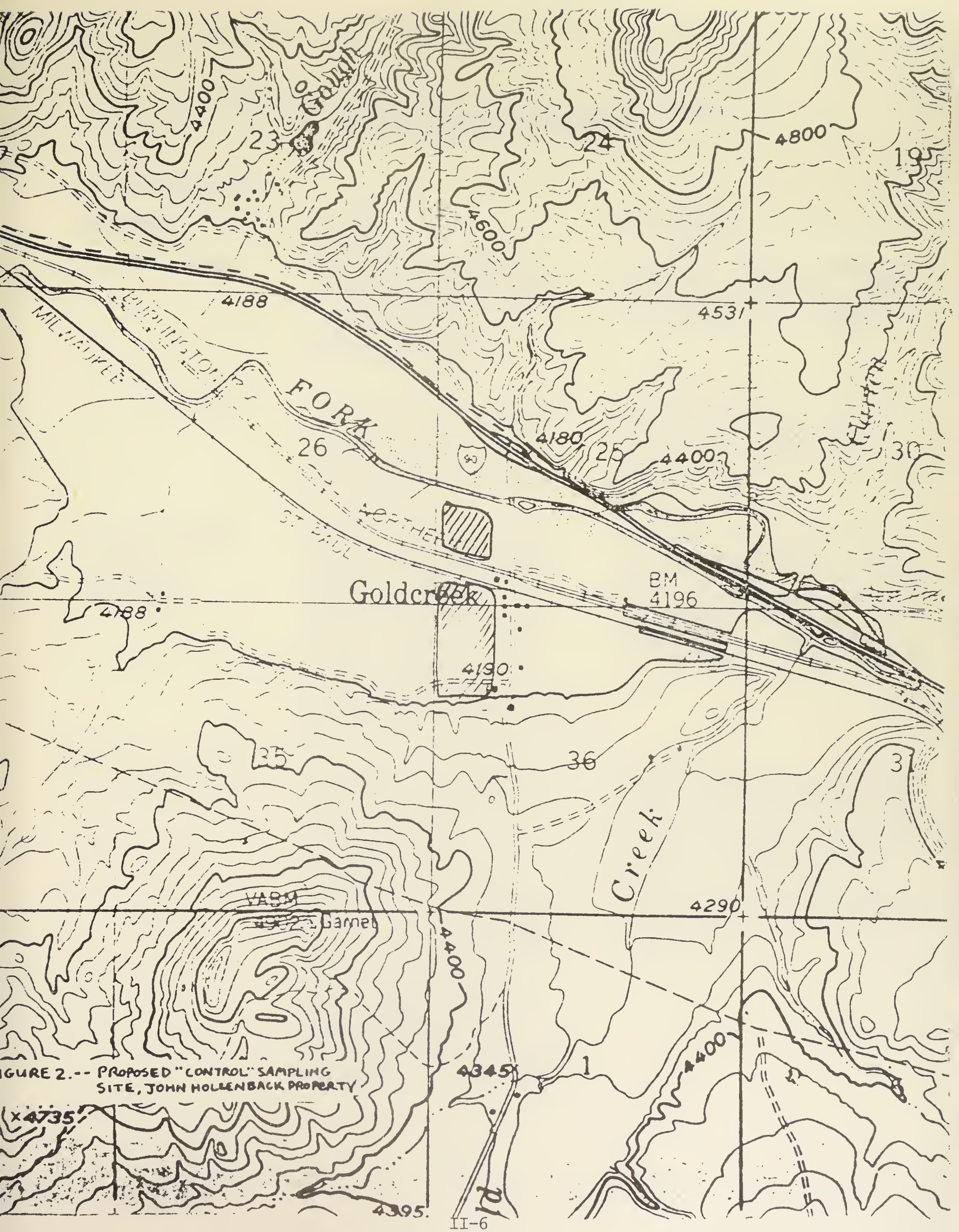
B. postpone all agricultural sampling until early July.

Implementation of the option B could cause logistical problems with initiation of the proposed Phase II program, as it is scheduled to begin in mid-to-late-June. However, it is assumed that Phase II will be implemented only if the Phase I "pilot" study results can justify further RI efforts. Pursuit of the second option would allow completion of a scaled-down version of the Phase II studies by mid-September. Therefore, the second option is recommended as:

- it will allow time for complete agreement on the "representativeness" of each sampling site;
- it will allow time for completion of all necessary soils mapping (e.g., at Walt Konda's field);
- the schedule will be compatible with the proposed plant sampling (phenological) criteria; and
- it should minimize site access-sampling problems (e.g., saturated soils located near, or adjacent to, the Clark Fork River), even if the Giddings soil-coring machine is not used.

PERSONAL COMMUNICATIONS (CITED IN TEXT)

Rolfes, Tony, February 5, 1985. Soils scientist, USDA/SCS, Deer Lodge. Phone conversation.
Strom, Don, February 4, 1985. Crew chief (soils mapping), USDA/SCS, Whitehall Phone conversation.



IGURE 2.-- PROPOSED "CONTROL" SAMPLING SITE, JOHN HOLLENBACK PROPERTY

APPENDIX A--PERTINENT FINDINGS FROM TELEPHONE-RELATED OR OFFICE-RELATED INTERVIEWS

PART A. LANDOWNERS

Name/Date	Findings	Conclusions
G. Seitz/1-30-85	Uses Mill Creek and wells for agricultural/domestic purposes, not SBC or CFR waters and doesn't own property adjacent to either stream/river.	As heavy metals data indicates phytotoxic conditions, suspect the major source to be smelter stack particulate fallout.
J. Archer/1-28-85	Uses Flint Creek and a well for agricultural/domestic purposes, not SBC or CFR waters. Doesn't utilize lands near SBC or Clark Fork River.	Heavy metal fallout from stack is suspected source of copper poisoned sheep, gardening problems and possibly the recent death of a cow.
Ms. Dody Weller/ 1-29-85 (H. Fergeson property)	They have property along SBC that has been contaminated with mill tailings; the land,"looks like a desert", as nothing will grow there. In regards to past sampling by the USEPA (previous memo), this does not appear to be true (Mr. Jim Dunn, pers. comm. 2/4/85).	This site meets SBC proximity/ tailings contamination criteria. However, he may be difficult to work with given his past association with the ACM/Mt. Haggin Ranch operations (Mr. Huey Long, office interview, 1/30/85)
H. Kellicut/1-28-85	They have an ~8-acre hayfield which is flooded by the CFR during the Spring, and which is subirrigated by the river throughout the growing season. She recalled one comment from the laboratory report sheet that, "they should mine, rather than farm, the soil." The field was sampled by Dave Streufert, but his copy of the analytical report was lost in the May, 1981 flood (in Deer Lodge).	This site meets CFR proximity/ tailings contamination criteria. As their garden has been sampled by the USEPA, and as their well is being sampled by Stiller et al., it would provide an interesting food-chain study to sample the field's soil, hay as well as animals that consume the hay.

PART A. LANDOWNERS (Continued)

Name/Date	Findings	Conclusions
H. Spangler/2-4-85	She has large tracts of land which used to be irrigated using SBC water and which still exhibit plant growth problems. Such lands haven't been irrigated using SBC for at least 40 years.	These sites meet SBC proximity and SBC flood irrigation criteria. Given the low probability of "Legacy Program" efforts occurring on her property this summer(Mt. Std., 2/2/85, p.7) sampling at the established test plots should be considered instead. Alternatively, sampling sites could be located in planted grass situated in T4NR1OW, NE 1/4 of section 36.
W. Konda/1-30-85	Portions of his sub-irrigated native hay-lands are contaminated with tailings (along SBC). Has tried to reclaim the lands with lime, but not successful.	Remains as a promising study site.
A. Peterson/1-28-85	Has alfalfa and oat fields situated adjacent to the old "Yellow Ditch" (fed by SBC) that have high As levels. Deep plowing has not been effective, while they haven't tried fertilizer or lime.	Remains as a promising study site.
D. Forsen/1-29-85	Reiterated has problems with irrigated haylands situated between the CFR and Valiton Ditch (fed by CFR). Mr. Huey Long, SCS, noted that the soil unit common to this area (i.e., "318", Baggs series) has been contaminated by heavy metals.	Remains as a promising study site.
H. Long/1-30-85	Reiterated his knowledge of "slickens" (soil mapping unit "5" typic fluvaquents-slickens complex).	Remains as a promising study site.

PART A. LANDOWNERS (Continued)

Name/Date	Findings	Conclusions
C. Benson/2-4-85	Has considerable acreages of mill tailings and irrigation water-affected lands within Sections 16, 21, 28, and 33 in T7NR9W; is very willing to cooperate with study, saying that he, "will even dig the [test] holes himself if need be". Also has a 900 head of cattle, some of which feed in the river bottoms--several cattle have become sick, but he is not sure of the reason (but could be related to salinity levels in forage).	An excellent prospect for sampling of soils-sediment, crops and livestock.

PART B. INTERVIEWS WITH SOIL CONSERVATION SERVICE PERSONNEL.

H. Long and T. Rolfes/1-31-85 (Deer Lodge SCS)	Soils maps were acquired for the Fergeson, Long, Peterson and Spangler sites; no such data exists for the Beck, Benson, Forsen or Kellicut sites. Short descriptions of each soil unit mapped by the SCS were also acquired.	Additional soils mapping will be required, if all sites given in Table 1, Part A are to be sampled.
D. Strom/2-4-85 (Whitehall SCS)	Although they are avoiding large-scale mapping in Silver Bow until the temperature-chemical complexities can be worked out, he will try to have someone do preliminary mapping at the Konda site early this summer.	Appears as though SCS will perform necessary mapping; I will follow-up in May, 1985.

APPENDIX B.--SOIL MAPPING UNIT DESCRIPTIONS (AS CITED IN TEXT)

Mapping Unit Name/Code	Description
Aquolls and Aquents, undifferentiated/4	"These are unnamed Aquolls and Aquents which are deep, poorly drained soils formed in recent alluvium. The texture of the profiles are highly variable in these young soils. However they often have loamy, sandy or silty upper profile textures with underlying materials of very gravelly loamy sand and sand being common. They are on flood plains. Native vegetation consists of water tolerant grasses and shrubs with abundant brush. They are occasionally flooded. Slopes range from 0 to 4 percent."
Typic Fluvaquent-Slicken Complex/5	"This is a complex of 45 percent Fluvaquents and 40 percent Slickens. They are occasionally flooded. Slopes range from 0 to 4 percent. Fluvaquents are deep, poorly drained soils formed in recent alluvium. The textures have loamy, silty or sandy upper profiles which are low in rock fragment content. It is common to have a very gravelly loamy sand or sand underlying material within the profile. These soils are on floodplains. Native vegetation consists of water tolerant grasses and shrubs with abundant brush. Slickens is a miscellaneous land type with soil textures similar to those described for the Fluvaquents above. However slickens have additional accumulations of fine textured material which originated from tailings from mining operations. The tailings were washed away and deposited in periods of high flood waters down-stream. These soils are along Silver Bow Creek and the Clark Fork River. They are largely unvegetated due to the contamination of the surface layer."
Baggs/31	Forthcoming (did not arrive as of 2/8/85).

Source: USDA/SCS. 1985. Soils Short Descriptions. Received from Huey Long and Tony Rolfes during the office visit on 1-31-85.

INITIAL REVIEW DRAFT

Tentative Series
HAL
4/82

ANACONDA SERIES

The Anaconda series consists of deep, well drained soils that formed in calcareous alluvium. These soils are on fans and stream terraces in valleys and uplands. Slopes are 0 to 60 percent. Mean annual precipitation is about 12 inches, and mean annual temperature is about 43°F.

Taxonomic Class: fine-loamy, mixed Aridic Haploborolls

Typical Pedon: Anaconda loam, in cropland. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 8 inches; brown (10YR 5/3) loam, dark brown (10YR 3/3) moist; platy structure parting to moderate fine granular; loose; very friable, nonsticky and nonplastic; common fine and coarse roots; neutral (pH 6.8); clear smooth boundary. (3 to 9 inches thick)

Bw--8 to 14 inches; yellowish brown (10YR 5/4) loam, dark brown (10YR 4/3) moist; weak medium subangular blocky structure; soft, friable, slightly sticky and slightly plastic; common fine and coarse roots; many fine irregular pores; neutral (pH 7.0); clear wavy boundary. (3 to 7 inches thick)

Bk1--14 to 27 inches; white (10YR 8/2) loam, light yellowish brown (10YR 6/4) moist; massive; soft, friable, nonsticky and nonplastic; few fine roots; many fine irregular pores; common fine soft masses of lime; violently effervescent; 5 percent pebbles; moderately alkaline (pH 8.4); clear wavy boundary. (6 to 17 inches thick)

Bk2--27 to 60 inches; very pale brown (10YR 8/3) sandy loam, light yellowish brown (10YR 6/4) moist; massive; soft, friable, nonsticky and nonplastic; few fine roots; many fine irregular pores; 15 percent pebbles; common fine soft masses of lime; strongly effervescent; moderately alkaline (pH 8.4).

Type Location: Powell County, Montana; 500 feet north and 600 feet west of the SE corner of sec. 19, T. 7 N., R. 9 W.

Range in Characteristics:

Soil temperature:	43 to 47°F.
Depth to k horizon:	10 to 16 inches
Mollic epipedon thickness:	7 to 9 inches

Ap horizon:

Hue:	10YR
Value, dry:	5
Value, moist:	3
Chroma:	1 through 3
Texture, <2 mm:	loam or clay loam
Clay content:	18 to 30 percent
Rock fragments:	0 to 5 percent
Pebbles:	0 to 5 percent
Reaction:	pH 6.1 to 7.3

Bw horizon:

Hue:	10YR
Value, dry:	4 through 6
Value, moist:	3 through 5
Chroma:	3 or 4
Texture, <2 mm:	loam or clay loam
Clay content:	20 to 35 percent
Rock fragments:	0 to 5 percent
Pebbles:	0 to 5 percent
Reaction:	pH 6.6 to 7.3

Bk1 horizon:

Hue:	10YR
Value, dry:	7 or 8
Value, moist:	5 through 7
Chroma:	2 through 4
Texture, <2 mm:	loam, sandy loam, or sandy clay loam
Clay content:	18 to 27 percent
Rock fragments:	5 to 15 percent
Cobbles:	0 to 5 percent
Pebbles:	5 to 10 percent
CaCO3 equivalent:	15 to 35 percent
Reaction:	pH 7.9 to 9.0

Bk2 horizon:

Hue:	10YR
Value, dry:	5 through 8
Value, moist:	4 or 6
Chroma:	3 or 4
Texture, <2 mm:	sandy loam or loam
Clay content:	15 to 25 percent
Rock fragments:	15 to 25 percent
Cobbles:	0 to 5 percent
Pebbles:	15 to 20 percent
CaCO3 equivalent:	5 to 20 percent
Reaction:	pH 7.9 to 8.4

Competing Series: These are the Boxwell and Kremlin series. The Boxwell soils have a paralithic contact at a depth of less than 40 inches. The Kremlin soils do not have a calcic horizon.

Anaconda Series

Geographic Setting: Anaconda soils are on fans and stream terraces in valleys and uplands. Elevations are 4,000 to 5,000 feet. Slopes are 0 to 60 percent. These soils formed in calcareous alluvium. The climate is cool, with long, cold winters; moist springs; and hot, dry summers. Mean annual precipitation is 10 to 14 inches. Mean annual temperature is 41 to 45°F. The frost-free season is 95 to 110 days.

Geographically Associated Soils: These are the Cetrack, Varney, and Beaverell soils. The Cetrack soils have very gravelly sand at a depth of 20 to 40 inches. The Varney soils have an argillic horizon. The Beaverell soils have very gravelly sand at a depth of 10 to 20 inches.

Drainage and Permeability: Well drained; slow to rapid runoff; moderate permeability.

Use and Vegetation: Anaconda soils are used as nonirrigated and irrigated cropland and rangeland. Potential native vegetation is mainly bluebunch wheatgrass, green needlegrass, needleandthread, fringed sagewort, and Sandberg bluegrass.

Distribution and Extent: Western Montana valleys. It is inextensive.

Series Proposed: Powell County, Montana, 1977.

National Cooperative Soil Survey
U.S.A.

REVISED DRAFT

Tentative Series
RRB, JH, AA, RER
Rev. 1/83

VARNEY SERIES

The Varney series consists of deep, well drained soils that formed in alluvium. These soils are on fans, terraces, foot slopes, and hills. Slopes are 0 to 45 percent. Mean annual precipitation is about 13 inches, and mean annual temperature is about 40°F.

Taxonomic Class: Fine-loamy, mixed Aridic Argiborolls

Typical Pedon: Varney clay loam, cultivated. (Colors are for dry soil unless otherwise noted.)

Ap--0 to 5 inches; grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine and very fine granular structure; slightly hard, friable, slightly sticky and slightly plastic; many fine and very fine roots; many fine and very fine interstitial pores; 5 percent pebbles; neutral (pH 6.6); clear smooth boundary. (4 to 7 inches thick)

Bt--5 to 15 inches; brown (10YR 5/3) clay loam, dark brown (10YR 4/3) moist; moderate medium and fine subangular blocky structure; hard, friable, sticky and plastic; many fine and very fine roots; common fine tubular pores; many thin continuous clay films on faces of peds; 10 percent pebbles; neutral (pH 7.3); clear irregular boundary. (5 to 13 inches thick)

Bk1--15 to 28 inches; light gray (10YR 7/2) gravelly sandy clay loam, pale brown (10YR 6/3) moist; weak coarse prismatic structure; slightly hard, friable, slightly sticky and nonplastic; common fine and very fine roots; common fine and very fine pores; 15 percent pebbles and 5 percent cobbles, common fine white (10YR 8/2) soft masses of lime; violently effervescent; moderately alkaline (pH 7.9); gradual smooth boundary (10 to 25 inches thick)

Bk2--28 to 48 inches; very pale brown (10YR 7/3) gravelly sandy loam, pale brown (10YR 6/3) moist; massive; soft, friable, slightly sticky and nonplastic; few fine roots; few fine pores; 15 percent pebbles and 5 percent cobbles; disseminated lime; strongly effervescent; moderately alkaline (pH 7.9); clear smooth boundary. (5 to 25 inches thick)

BC--48 to 60 inches; light brown (7.5YR 6/4) stratified gravelly sandy loam and gravelly loamy sand, brown (7.5YR 5/4) moist; massive; slightly hard, friable, slightly sticky and nonplastic; few fine roots; few fine pores; 20 percent pebbles and 5 percent cobbles; slightly effervescent; moderately alkaline (pH 8.4).

Type Location: Madison County, Montana; 2,400 feet north and 2,300 feet west of the SE corner of sec. 32, T. 2 S., R. 1 W.

Range in Characteristics:

Soil temperature:	40 to 44°F.
Mollic epipedon thickness:	7 to 10 inches
Control section:	argillic horizon with 30 to 35 percent clay
Depth to Bk horizon:	9 to 20 inches

Ap horizon:

Hue:	10YR
Value, dry:	4 or 5
Value, moist:	2 or 3
Chroma:	2 or 3
Texture, <2 mm:	clay loam, loam
Clay content:	27 to 32 percent
Rock fragments:	0 to 50 percent
Cobbles:	0 to 15 percent
Pebbles or channers:	0 to 35 percent
Reaction:	pH 6.6 to 7.3

NOTES: Uncultivated areas have a 2- to 4-inch A horizon that is loam or gravelly loam.

Bt horizon: (In some pedons the upper 2 to 4 inches meet the requirements for a mollic epipedon.)

Hue:	10YR or 2.5Y
Value, dry:	4, 5, or 6
Value, moist:	3, 4, or 5
Chroma:	2, 3, or 4
Texture, <2 mm:	clay loam or sandy clay loam
Clay content:	30 to 35 percent
Rock fragments:	5 to 35 percent
Cobbles:	0 to 5 percent
Pebbles:	5 to 30 percent
Reaction:	pH 6.6 to 7.8

Bk horizon:

Hue:	10YR or 2.5Y
Value, dry:	6, 7, or 8
Value, moist:	4, 5, 6, or 7
Chroma:	2, 3, or 4
Texture, <2 mm:	sandy loam, loam, or sandy clay loam
Clay content:	10 to 30 percent
Rock fragments:	5 to 35 percent
Cobbles:	0 to 5 percent
Pebbles:	5 to 30 percent
CaCO3 equivalent:	15 to 30 percent
Reaction:	pH 7.4 to 8.4

BC horizon:

Hue:	7.5YR, 10YR, or 2.5Y
Value, dry:	5, 6, or 7
Value, moist:	4, 5, or 6
Chroma:	2, 3, or 4
Texture, <2 mm:	loamy sand or sandy loam stratified with loam
Clay content:	5 to 15 percent
Rock fragments:	5 to 35 percent
Cobbles:	0 to 5 percent
Pebbles:	5 to 30 percent
Reaction:	pH 7.9 to 8.4

Competing Series: These are the Assiniboine, Bostwick, Cheeseman, Crittenden, Duffson, Evanston, Jarre, Joplin, Kevin, Marmarth, Morval, Notter, Nuley, Perrypark, Peyton, Telstad, Turret, and Villa Grove series. Assiniboine soils have 45 to 60 percent sand in their Bt horizon. Bostwick, Jarre, Peyton, and Turret soils are noncalcareous to a depth of 40 inches or more. Cheeseman, Duffson, and Marmarth soils have bedrock at depths of 20 to 40 inches. Also, Cheeseman soils have hues of 5YR or redder. Crittenden soils lack a calcic horizon, have sandy skeletal 2C horizons below a depth of 25 inches, and have bedrock at depths of 40 to 60 inches. Evanston soils lack a calcic horizon and stratified materials below 30 inches. Joplin, Kevin, and Telstad soils formed in glacial till with high bulk density at depths of less than 40 inches, and they lack a calcic horizon. Morval soils lack a calcic horizon and occur in a climate that has 16 to 18 inches annual precipitation. Notter soils have loamy-skeletal C horizons. Nuley soils have a gravelly coarse sand 2C horizon below a depth of 15 inches and bedrock at depths of 40 to 60 inches. Perrypark soils are noncalcareous to a depth of 40 inches or more, have hue of 5YR or redder, lack gravel in the C horizon, and occur in a climate that has 17 inches annual precipitation. Villa Grove soils lack a calcic horizon and have a horizon of gypsum accumulation.

Geographic Setting: Varney soils are on fans, terraces, and foot slopes. Elevations are 4,500 to 6,000 feet. Slopes are 0 to 45 percent. These soils formed in alluvium. The climate is cool and semiarid. Mean annual precipitation is 10 to 14 inches. Mean annual temperature is 38 to 42°F. The frost-free season is 90 to 125 days.

Drainage and Permeability: Well drained; slow to rapid runoff; moderately slow permeability.

Use and Vegetation: These soils are used for irrigated and dryland crops and as rangeland. The potential native vegetation is mainly bluebunch wheatgrass, western wheatgrass, needleandthread, and green needlegrass.

Distribution and Extent: Terraces and fans of the intermountain valleys in southwestern Montana. The series is moderately extensive.

Series Proposed: Madison County Area, Montana, 1977.

Remarks: Varney is a place name.

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VASTINE SERIES

The Vastine series consists of deep, poorly to somewhat poorly drained soils that formed in mixed alluvium. Vastine soils are on low terraces and floodplains with slopes of 0 to 5 percent. The mean annual precipitation is about 7 inches and the mean annual temperature is about 42°F.

Taxonomic Class: Fine-loamy over sandy or sandy-skeletal, mixed, frigid Typic Haplaquolls.

Typical Pedon: Vastine loam - grassland. (Colors are for dry soil unless otherwise noted.)

A1—0 to 10 inches; dark gray (10YR 4/1) loam, black (10YR 2/1) moist; moderate very fine granular structure; soft, very friable; mildly alkaline (pH 7.8); gradual smooth boundary. (10 to 24 inches thick)

B2g—10 to 30 inches; light brownish gray (2.5Y 6/2) loam, dark grayish brown (2.5Y 4/2) moist; many large prominent mottles of dark gray (N 4/) and olive brown (2.5Y 4/6) moist; moderate medium subangular blocky structure; slightly hard, very friable, slightly plastic; mildly alkaline (pH 7.8); abrupt smooth boundary. (14 to 34 inches thick)

IIC—30 to 60 inches; gray (10YR 5/1) sand, dark gray (10YR 4/1) moist; common medium distinct olive brown (2.5Y 4/6) mottles; single grained; loose; mildly alkaline (pH 7.8).

Type Location: Alamosa County, Colorado; 2,550 feet east and 300 feet north of the SW corner of sec. 30, T.38N., R.9E.

Range in Characteristics: Mean annual soil temperature ranges 43° to 45°F., and mean summer soil temperature ranges 60° to 62°F. The soils range from slightly acid to moderately alkaline in a majority of subhorizons in the control section. Exchangeable sodium ranges from 0 to 15 percent in the control section except that a few subhorizons that exceed those ranges occur discontinuously in some pedons. The upper part of the control section has 15 to 35 percent fine or coarser sand 0 to 15 percent rock fragments. The rock fragments are dominantly 1 to 10 inches in diameter. The depth to the IIC horizon ranges from 24 to 40 inches below the surface.

The A horizon has hue of 5Y through 7.5YR, value of 4 or 5, 2 or 3 moist, and chroma of 1 or 2.

The B2g horizon has hue of 5Y through 7.5YR, value of 4 through 6, 2 through 5 moist, and chroma of neutral to 6. In some pedons, colors are variegated in this horizon.

The IIC horizon has hue of 5Y through 7.5YR, value of 5 or 6, 4 or 5 moist, and chroma of 1 or 3. In some pedons, colors in this horizon are variegated.

Competing Series: This is the Gerrard series. Gerrard soils have sandy-skeletal substrata at depths of 10 to 20 inches.

Geographic Setting: Vastine soils are on low terraces and floodplains. Slope gradients range from 0 to 5 percent. These soils formed in mixed alluvium. The average annual precipitation is 7 to 9 inches, with peak periods of precipitation in the spring and early summer months. High water tables keep the soil wet in most seasons. Mean annual temperature is 40° to 44°F., and mean summer temperature is 59° to 61°F.

Geographically Associated Soils: These are the Medano and Nortonville soils. Medano soils are coarse-textured. Nortonville soils have a calcic horizon.

Drainage and Permeability: Poorly to somewhat poorly drained; slow runoff; moderate permeability. Typically the water table fluctuates with the height of the water in the adjacent streams. These soils are sometimes flooded in the spring. Water tables may drop as much as 5 feet in the driest parts of the year.

Use and Vegetation: These soils are used principally as native pastureland and for irrigated meadows. Occasionally, some areas are used for small grains. Principal native plants are sedges, rushes, saltgrass, and other water-tolerant grasses and plants.

Distribution and Extent: High mountain valleys of central Colorado. The series is of moderate extent.

Series Established: Rio Grande County, Colorado, 1972.

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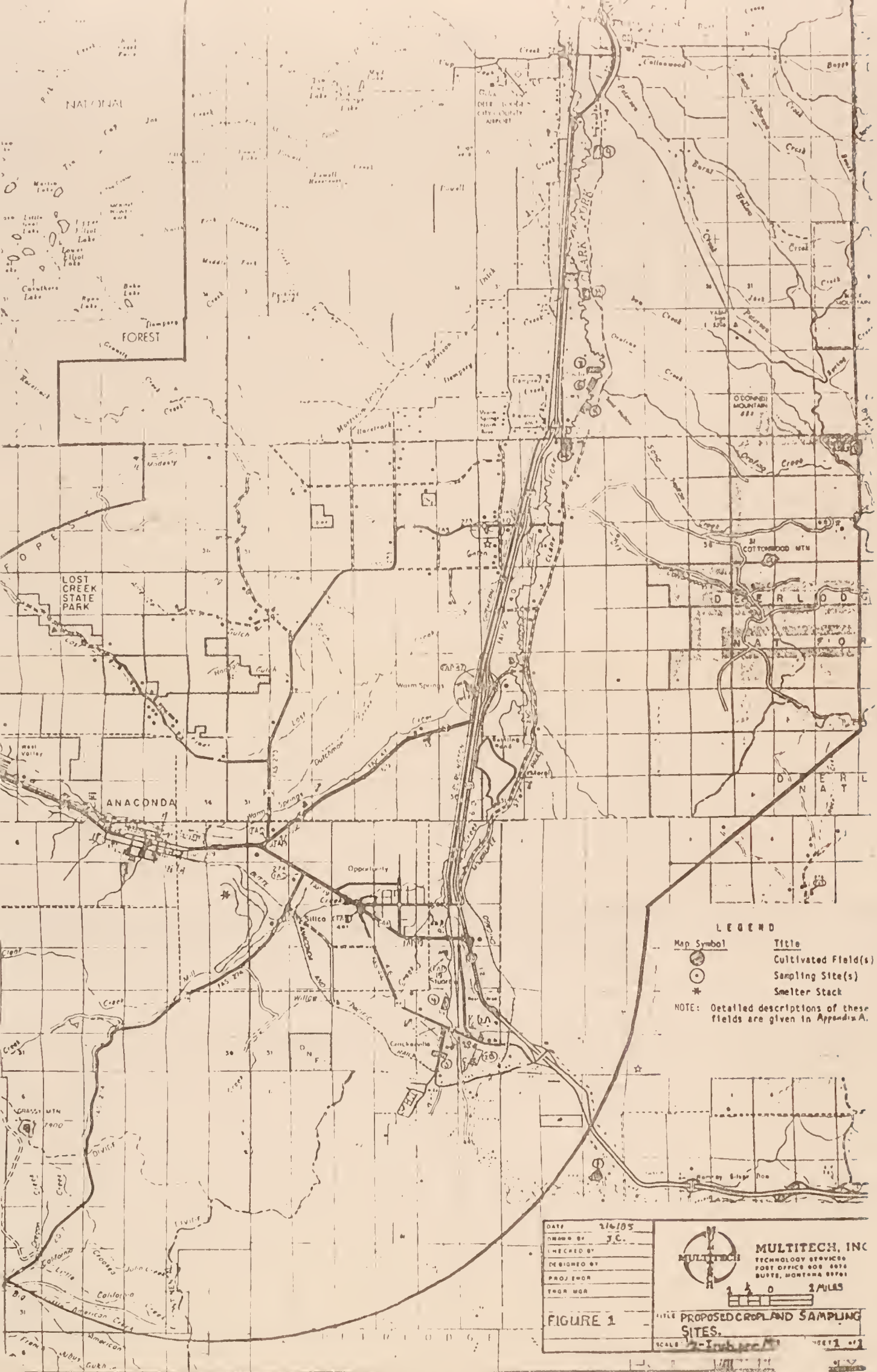
NATIONAL
FOREST
LOST CREEK STATE PARK
ANACONDA
Opportunity
Silico
Warm Springs
Willow
Creek
COTTONWOOD MTN
O'CONNELL MOUNTAIN
LEGEND
Map Symbol
Title
Cultivated Field(s)
Sampling Site(s)
Smelter Stack
NOTE: Detailed descriptions of these fields are given in Appendix A.
DATE 2/6/85
DRAWN BY J.C.
CHECKED BY
DESIGNED BY
PROJ ENGR
PROJ MGR
FIGURE 1
MULTITECH, INC
TECHNOLOGY SERVICES
POST OFFICE BOX 4976
BUTTE, MONTANA 59701
2 1 0 2 MILES
TITLE PROPOSED CROPLAND SAMPLING SITES.
SCALE 2-Inch per Mile
SHEET 1 of 1

United States
Department of
Agriculture

Soil
Conservation
Service

Rec'd 2/12/85
February 11, 1985

Mr. Jay Cornish
Multi-Tech
P.O. Box 4078
Butte, MT 59702

Dear Mr. Cornish,

We needed to supply you with an additional soils description for the 31 and 131 unit soils. These are as follows.

31 BAGGS
The Baggs series consists of deep. well drained soils formed in alluvium. Typically they have a clay loam surface layer 6 inches thick. The subsoil is a heavy clay loam and the substratum is a gravelly light clay loam. They are on fans, terraces and foot-slopes. The native vegetation is mainly mid and short grasses. The 131 soil is like the 31 unit except that the 131 unit has a cobbly clay loam surface layer.

If you need any additional information on these or other units please contact our office. Thank you.

Sincerely,

Tony Rolfes
Soil Scientist
Deer Lodge Field Office

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT III

DETAILED ANALYTICAL METHODS FOR SOILS

III.1 MECHANICAL (HYDROMETER) ANALYSES
III.2 SULFATE/K EXTRACTION
III.3 TOTAL S IN SOLIDS

MultiTech

III.1

HYDROMETER ANALYSIS FOR SOLID'S SAND, SILT AND CLAY CONTENT

Summary

This method is based upon the principle that large particles settle at a faster rate than the same kind of small particles. (Stokes' Law) Thus, the concentration of soil particles in aqueous suspension at a given time is dependent upon the size of the particles. The soil particles are put into suspension via mechanical stirring and maintained there with the aid of a dispersing agent. Sodium (hexa) metaphosphate solution disperses the soil and prevents flocculation of the clays. As stated in Sobek et al. (1978, p. 122), " sodium replaces exchangeable calcium and the precipitation of the calcium, in the form of calcium phosphate, prevents its recombination with the clays. The net negative charge on the clay particles increases due to the addition of sodium ions, causing the particles to repel each other and disperse".

Reference

The procedure is based on Section 3.4.3 "Particle Size Analysis" in Sobek et al.'s (1978) Field and Laboratory Methods Applicable to Overburdens and Minesoil.

Procedure

1. Weigh 50 gms dried (@ 40± 1°C), -2 mm mesh, fine-textured material (e.g., most soils) or 100 gms coarse-textured material

(e.g., mill tailings) to the nearest 0.01 gm using a top loading balance. This constitutes the "raw" sample. Prepare duplicate samples at a frequency of 1:20.

2. Pour each sample into a clean 600 ml beaker and add 100 ml of Calgon® solution (100 gms. solid made up to 1 L with DI water) then 400 mL DI water. Allow the suspension to stand for 1 hr, stirring approximately 1 min every 10 to 15 min.

3. Wash each beaker's contents into a 1.0 L sedimentation jar and place in a vibration-free spot. Make up to volume (i.e., fill to the 1.0 L mark) using DI water, then record the suspension's temperature to the nearest °F.

4. Insert the plunger and mix until all the sediment is thoroughly disposed and is off the bottom of the cylinder. Remove the plunger, then immediately start the timer.

Note: If the surface of the suspension is very foamy, add one drop of amyl alcohol and remix. If only one timer is available, record the time--to the nearest second--after stirring each cylinder.

5. Gently insert the hydrometer into the first cylinder about 10 sec before making the 2-min reading

Note: All readings will use the same hydrometer, for a given batch of samples).

Record the reading, measuring at the top of the meniscus, then remove within 10 sec after making the reading. Measure and

record the temperature of the suspension to the nearest °F. Repeat this process for each of the remaining cylinders in the batch.

6. Repeat Step 5 for the 120-min reading. Calculate the temperature-corrected readings as follows: (a) if T≥ 68°F, add 0.2 gm/L^{-1} per °F, or (b) if T< 68°F, subtract 0.2gm/L^{-1} per °F.

7. Upon completion of the 120-min reading (per cylinder), quantitatively transfer the contents onto a 200 mesh screen, washing inside the cylinder and screen with tap water. Continue washing the screen's contents until the washings are clear; the material remaining on the screen is the sand fraction.

8. When the washing step is completed, quantitatively transfer the sand fraction into a 250 mL beaker that has been previously dried at 105± 1°C (for 4-6 hrs.), then weighed, after cooling to room temperature in a desiccator, to the nearest 0.01 gm. on a top loading balance.

9. Dry the beaker and its contents at 105± 1°C to constant weight (± 0.01 gm). Also, dry 10 gm (recorded to nearest 0.01 gm) of original sample @ 105 ± 1°C to constant weight. This constitutes the "check" sample.

10. Each sample's sand, silt and clay contents are calculated on an oven dried basis as follows:

--Calgon (dispersing agent) correction factor: temperature-corrected 2 min reading for the blank.

Note: Prepare one blank for each batch of Calgon solution used and for each hydrometer used.

--Weight-corrected 120-min reading: temperature-corrected 120-min hydrometer reading minus the Calgon correction factor.

--% Clay: (weight-corrected 120-min reading ÷ air dry weight of "raw" sample) x CF x 100.

--% Sand: $\left[\frac{\text{(beaker + sand), gms - beaker, gms}}{\text{air dry wt. of "raw" sample x CF}} \right] \times 100$

--% silt: 100 - (% clay + % silt).

where $CF = \frac{\text{air dry weight of "check" sample}}{\text{oven dried weight of "check" sample}}$

III.2

TURBIDIMETRIC DETERMINATION OF SOIL SULFATE

Summary

Sulfate ion is precipitated in a hydrochloric acid/ammonium acetate medium with barium chloride, forming barium sulfate crystals of uniform size. The amount of milky white turbidity formed is directly proportional to the amount of sulfate ion present. Light absorbance of the barium sulfate suspension is measured spectrophotometrically, with the sulfate ion concentration being determined by comparison with measurements of standard solutions. Because barium sulfate suspension loses its stability at high concentration, standards exceeding 50 mg/L are considered unstable and therefore invalid. Samples containing >50 ppm sulfate, must be diluted with 1.0N ammonium acetate extraction solution at the set pH (i.e., pH 7 or 5.5).

Reference

The procedure is based on Method 375.4, Methods for Chemical Analysis of Water and Wastes, USEPA Publication No. EPA- 600/4-79-020, as revised March 1983.

Procedure

1. Select samples and quality control samples as required. Leave samples out to reach room temperature.

2. Prepare standards of 0, 10, 20, 30, 40 and 50 mg/L S as SO_4^{-2} ion from a 2500 mg/L as SO_4^{-2} stock solution. Use 1.0N ammonium acetate (of the appropriate pH) for all dilutions.

3. Warm up the dual-beam spectrophotometer and set the wavelength to 420 nm. The instrument is zeroed with matched 1-or 4-cm. path cuvettes containing ammonium acetate extractant solution placed in both the sample and reference beams.

4. Place 10.0 ml aliquot of sample or QA/QC extract into a 25 ml scintillation vial or Erlenmeyer flask. Add 0.70 ml AR grade 12MHCl, then 0.50 ml of conditioning reagent.

Note: To prepare conditioning reagent, mix 30 ml. of conc. HCl with 300 ml DI water. Add 100 ml. of 95% ethanol or isopropanol. Dissolve 75 gms AR-grade NaCl in this solution, then add 50 ml of glycerol and mix.

Swirl the solution to mix well, then fill the reference cuvette with the acidified conditioning reagent. Next, add a small scoop (0.05-0.10 cc) of AR grade $BaCl_2$ to the remainder of the solution (in the vial or flask), and then start the timer. Swirl the solution for 1 minute, then pour into the sample cuvette.

Note: Periodically check the sample cuvette for cloudiness. If the surface appears cloudy, soak the cuvette for several minutes in 12 M HCl to remove the $BaSO_4$ film. The sample and reference cuvettes then are filled with ammonium acetate solution and the instrument rezeroed.

5. Insert the sample and reference cuvettes into the spectrophotometer and allow the digital reading to equilibrate-stabilize. The sample must remain undisturbed in the instrument until full turbidity is developed (as determined by the digital readout). The reaction is considered complete when no further increase in absorbance occurs over several minutes. For samples containing low concentrations (<10ppm) of sulfate, the development of $BaSO_4$ can take as long as 15 or 20 min; however, five minutes is usually sufficient. If the absorbance increases and then begin to decrease, record the maximum absorbance value obtained.

6. Plot absorbance vs. concentration for the standards and, using a polynominal least-squares computer program, calculate the least-squares coefficients and the correlation coefficient. Select the degree of the polynomial that gives the best correlation coefficient; however, the degree of the polynomial must be, at most, one less than the number of data points. If the correlation coefficient is 0.998 or greater, the calibration curve is acceptable. If not, recalibrate.

   Alternatively, the absorbance and standards data may be plotted and the calibration curve constructed by hand.

Note: During the analytical run do at least two additional determinations of the zero standard or the next lowest standard.

Calculate 3 times the standard deviation of the replicate low-level measurements, and report this value as the MDL.)

7. Determine the absorbance of samples in the same manner as for standards (see Step 4).

8. Concentration values for unknown samples are determined by using either the least-squares program, or by taking values from the hand-constructed standard curve. Dilution factors then are taken into consideration to yield the adjusted sulfate concentration.

9. Analysis of analyst-prepared quality control samples at the frequency specified in the quality control (QC) plan is required. If the quality control samples are within the QC plan control limits, the analysis is complete. If not, take the corrective action as specified in the QC plan.

10. Record "in control" results on preliminary report forms, or on the computer Laboratory Information Management System, as directed.

III.3

TOTAL SULFUR DETERMINATION IN SOLIDS

Summary

The solid sample is heated with an excess of Eschka's mixture in a muffle furnace, thus converting the sample's sulfur to various sulfate salts. These salts are dissolved in water, liberating the sulfate ion. The solution is filtered, and sulfate content determined either by gravimetry or turbidimetry via precipitation with barium chloride to form barium sulfate.

References

ASTM Method 3177-82, AOAC Methods 3.108-3.110 (1984) and USEPA Method 375.3(3/83).

Procedure

1. Weigh ~1 gm solid, to the nearest 0.1 mg using an analytical balance. Thoroughly mix the sample with ~3 gms. low-S Eschka's mixture (62 MgO:34Na_2CO_3% w/w) in a porcelain crucible using a glass stirring rod. Cover the stirred sample with an additional 1 gm of Eschka's mixture.

Note: The detection limit for 1 gm samples is about 0.008% (80 ppm) as S or 0.025% (250 ppm) as SO_4^{-2}. The maximum amount of sulfur that may be present in the sample if the gravimetric procedure is used is 0.15 gm, or 0.45 gm. as SO_4^{-2}.

2. Place each crucible in a "cold" (room temperature) muffle furnace and gradually raise the temperature to 800°C within about 1 hr.. Maintain the crucible(s) at this temperature for approximately 1-1/2 hrs or until all evidence of reduced carbon (black particles) have disappeared upon stirring. Turn off the furnace at this point.

3. Allow the crucible(s) to come nearly to room temperature before removing from the furnace. Transfer the contents of each crucible quantitatively to a 200 mL beaker using a small volume of DI water. Make up to ~100 mL with hot DI water and digest (extract) the ash for 1/2 to 3/4 hr--do not boil--with occasional stirring. If turbidimetric analysis is to be used, proceed to step 4, if gravimetric analysis is used, proceed to step 5.

4.(a) Filter the solution through Whatman No. 42 paper, collecting each filtrate in either a 125 mL. or 250 mL. volumetric flask.

Note: Use former size for vegetation and soils, and the latter for coal.

Thoroughly wash the insoluble matter trapped on the filter with ~50 or ~100 ml of hot DI water, as determined by volumetric flask volume. Discard the filter paper when washing is complete.

(b) Add 1:4 AR grade HCl to the filtrate until blue litmus paper just changes to pink, this volume should vary from 5 to 15 mL, as determined by filtrate volume.

(c) Dilute the slightly acidified filtrate with DI water to standard volume (i.e., 125 or 250 mL) and analyze by the turbidimetric sulfate procedure (see MultiTech Laboratory SOP Manual, pp. 3.2/3.3.

(d) Calculation:

$\%S = (x*y/z)* 3.33x10^{-5}$

Where:

x = mg/L sulfate in particular extract (corrected for digestion blank).

y = ml of extract (i.e., 125 or 250 mL normally).

z = gm of sample, corrected to oven dry weight basis, unless otherwise indicated.

(e) Proceed to step 6.

5(a) Filter the solution through Whatman No. 42 paper, collecting the filtrate into a 400 ml. beaker. Thoroughly wash the insoluble matter on the paper with ~5 mL hot DI water. Discard the filter paper when finished washing.

b) Add 1:4 AR grade HCl to the filtrate until blue litmus paper just changes to pink (~15 mL acid), then add another 0.5 mL of this same dilute acid solution.

(c) Bring the acidified solution to a gentle boil and add slowly, stirring constantly, 10 mL of 100g/L $BaCl_2$ solution.
The $BaCl_2$ must be in excess. If additional drops of this solution cause additional $BaSO_4$ precipitation, discard the solution (filtrate) and reds the analysis using a smaller weight of samples.

(d) Continue gentle boiling for 15 min, then allow the solution to stand for a least 2 hrs., or preferably overnight, at a temperature slightly below the boiling point.

(e) Filter the solution through Whatman No. 42 paper. Wash the filter's contents with hot DI water until 1 drop of 1.0 M $AgNO_3$ solution produces no more than a slight opalescence when added to 8-10 mL of filtrate.

(f) Place the wet filter paper/$BaSO_4$ precipitate into a crucible of known weight.

Note: Previously heat the crucible at 925°C until constant weight is attained, and weight is known to the nearest 0.1 mg.
Fold the paper loosely over the precipitate so as to prevent spattering, but yet allows free access of air. Smoke the paper off gradually, but never allow it to burn with a flame, in a muffle furnace by slowly increasing the temperature from ambient (~22°C) to 750°C over a period of 1 hr. After the paper is practically consumed, increase the temperature to 925°C and heat, for approximately 1 hr., to constant weight. Remove the

crucibles once they have cooled for ~1/2 hr. within the furnace.

(g) Finish cooling the crucible(s) in a desiccator and weigh each one to the nearest 0.1 mg. using an analytical balance.

(h) Calculations:

$\% S = (x-y/z) * 0.01373$

Where:

x = mg $BaSO_4$ recovered per sample.

y = mg $BaSO_4$ apparently recovered from the digestion blank.

z = gms sample, corrected to an oven dried weight basis.

(i) Proceed to step 6.

6. Similarly analyze all required QA/QC samples as done. Carry one digestion blank through the procedure for each batch of twenty (20) samples or fraction thereof.

7. The analyst prepared QC samples will be analyzed at the frequencies specified in the QA/QC plan. If the analytical results are within the QA/QC plan control limits, the analysis is complete. If not, take the appropriate corrective action specified in the plan.

8. Record the "in control" results on preliminary report forms, or on the computerized LIMS, as directed. All analysis preparation sheets, data sheets and preliminary report sheets, etc., will be filed as specified in the MultiTech Laboratory's SOP (pp. 1-38/ 1-40).

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SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT IV

DETAILED ANALYTICAL METHODS FOR PLANT MATERIALS

IV.1 WET ASHING
IV.2 TOTAL KJELDAHL NITROGEN DETERMINATION
IV.3 PHOSPHORUS DETERMINATION

MultiTech

ATTACHMENT IV.1

VEGETATION SAMPLE DIGESTION PRIOR TO TRACE ELEMENT ANALYSIS

Each dried, ground sample is hand-mixed in its storage vial by gentle tumbling for approximately 10- to 15-sec. Approximately one gram of sample is weighed into a tared 150 to 250 mL graduated beaker or Erlenmeyer flask; the container plus sample is weighed to the nearest 0.01 gm. via use of a toploading balance. If a replicate is required to meet internal QC protocols, a second 1-gm portion then is withdrawn from the storage vial and processed in the same manner as described above.

Sample Digestion

(1) Approximately 30 to 40 mL of Instra-Analyzed, concentrated nitric acid (HNO_3) is carefully dispensed to each "beaker"; if the sample material is believed to be high in protein, fatty, or resinous substances, the beaker or flask should be set in the fume hood for about 1/2 hour before heat is applied. This process is repeated for the NBS Standard Reference Materials, e.g., Orchard Leaves (NBS-SRM No. 1571) and Citrus Leaves (NBS-SRM No. 1572). A watch glass is placed on top of each beaker following addition of the acid. If flasks are utilized, insert the reflux cap at this time.

(2) The prepared containers are swirled gently to mix the acid with the plant materials. The inner walls are each washed with a small amount of AR-grade HNO_3 and placed on a hotplate which is then heated to 170°C. The reagent blanks are placed on the hotplate at this time.

(3) The containers' contents are allowed to digest gently until the expulsion of the reddish-brown NO_2 is nearly complete. The heat is then increased to 195°C to 200°C (taking care to avoid severe bumping or sample spattering) for about 11/2 hours or until the usually straw-colored liquid is reduced to a few mL volume.

(4) The inner walls of each container are rinsed with ~1 ml. of AR-grade, 30 percent H_2O_2. Approximately 5 mL AR-grade, concentrated perchloric acid ($HClO_4$) is then added to each "beaker", including the blanks.

(5) Each volume is reduced to near dryness at 200°C to 205°C without charring, until dense, white $HClO_4$ fumes fill the container. Several additional volumes ($\leq$ 2 mL total) of H_2O_2 can be added to each container while swirling to complete the decolorization-oxidation processes at this stage. Rapid or explosive oxidation problems resulting from perchlorate-organic matter reactions should not be observed, as the oxidation process is largely complete before final $HClO_4$ fuming. Heating is continued until the reappearance of white fumes.

(6) The completed digests and blanks are removed from the hotplate and several mL of DI water are added to each "beaker"; this serves to cool the reactions and dissolve the acid fumes into each digest solution. For those samples slated for Fe and Mn anlyses, add 3 drops AR-grade sulfuric acid plus 10 ml of DI water. Each solution is gently boiled for about 10 minutes, then removed from the hotplate and allowed to cool.

(7) Each cooled digest is filtered using either sintered glass disks under light vacuum or Whatman No. 42 ashless filter paper (or equivalent) into a 50 ml. volumetric flask. The watch glass, glass rod and filter paper are rinsed with two 10 ml portions of 1:100 NHO_3 and the rinsings collected in the volumetric flask. The volume is made up with 1:100 HNO_3. The analyte concentrations are determined either by appropriate flame or furnace atomic absorption methods or by ICAPES (USEPA 1983).

IV.2

DETERMINATION OF KJELDAHL NITROGEN (CRUDE PROTEIN)

MultiTech utilizes a Labconco® brand micro-Kjeldahl distillation unit to determine % Kjeldahl nitrogen in soil and plant materials. The method discussed below presumes the use of such as apparatus.

Sample Digestion

(1) Weigh a 0.20 gm portion from each sample vial to the nearest 0.1 mg (by using an analytical balance) and then carefully place into the 100 mL capacity micro-Kjeldahl flask.

(2) Add ~2 gms of AR-grade K_2SO_4. Any sample or salt trapped in the neck of the flask is washed to the bottom with a minimum volume of DI water.

(3) Pour approximately 10 mL of AR-grade concentrated sulfuric acid slowly down the neck of each flask. Too rapid addition of acid could cause the sample/water slurry to overheat, and possibly be expelled from each flask.

(4) Drop six to eight Hengar® selenized boiling granules into each flask, then place on the heater and adjust the heat to the "low" setting. The heating rate is slowly increased to a reading of "8" on the control dial. The heating rate is carefully monitored so as to avoid excessive foaming and subsequent loss of sample.

(5) Continue heating until the sample digest turns pale yellow to yellow-green. Keep the refluxing action to the lower half of each flask's neck; rotate flasks occasionally to keep solids exposed to the acid. 2 mL of acid may be added if the particular sample begins to bake on the inner walls of the neck.

Sample Distillation

(1) Bring the reservoir water to a boil.

(2) Carefully pour the sample into the sample inlet reservoir.

Note: Do not transfer solid matter (e.g., disintegrated boiling granules) into the inlet reservoir.

(3) Open the inlet stopcock and slowly add the sample to the distillation chamber.

Note: Too rapid an addition may result in sample flash-over because of the violent reaction of the concentrated sulfuric acid with residual water in the distillation chamber.

(4) Add about 5 mL of DI water to the micro-Kjeldahl flask and swirl.

(5) Add the washings to the inlet reservoir, open the inlet stopcock, and allow the washings to enter the distillation reservoir.

(6) Pour 30 to 35 mL of 45% (w/v) NaOH into a plastic graduated cylinder and then pour solution into the inlet reservoir.

(7) Pour 50 mL of 0.8 M H_3BO_3 into a 125 mL Erlenmeyer flask and add about 10 drops of bromocresol green-methyl red-mixed indicator solution (1% solution in methanol).

(8) Place the Erlenmeyer flask under the distillation apparatus so that the tip of the condenser is immersed in the boric acid.

(9) Slowly add the NaOH solution to the sample in the distillation chamber, pouring the NaOH down the side of the distillation chamber so that a minimum degree of mixing occurs.

Note: The NaOH reacts very violently with the sample's sulfuric acid and the addition must essentially be made dropwise. Also, care must be taken to do this steadily so that a vacuum is not created which will suck the boric-acid receiving liquid into the distillation chamber.

(10) After completion of the sodium hydroxide addition, continue the distillation until a total of 100 to 125 mL is in the receiving flask.

Note: The sample should turn a dark brown. Failure to do so usually indicates insufficient NaOH; consequently, add another 1 to 5 mL of NaOH solution.

(11) Remove the receiving flask and clean the distillation apparatus (described below). The liquid in the receiving flask is then titrated as follows.

Titration Step and Calculation of Percent Kjeldahl Nitrogen Content

(1) Quantitatively transfer the liquid from the receiving flask is transferred quantitatively to a 250 mL Erlenmeyer flask and titrate with ~0.1 N HCl (standardized to ± 0.0001N). Because the titrant volume used is often less than 5 mL the use of a

microburet graduated in 0.02 ml. divisions is imperative. This type of buret can be read to ± 0.005 ml. of volume.

(2) Calculate the percent Kjeldahl nitrogen from the equation:

$$\%N = \frac{(T_s - T_b) * (N) (14.01) (100)}{1000*(W)}$$

Where:

T_s = mL titration for sample where:
T_b = mL titration for blank
N = normality of standard hydrochloric acid
and W = gms of sample

An example of the calculation is given below:

Raw data $N = 0.0942$

$T_s = 1.94$

$T_b = 0.07$

$W = 1.9872$

$$\text{Kjeldahl N} = \frac{(1.94 - .07) (.0942) (14.01) (100)}{(1000) \quad (1.9872)}$$

$$= 0.12\%$$

Note: It is suggested that sample splits be analyzed for every 20th sample so as to check analytical precision. The accuracy of the results can be checked via analysis of reagent blanks and aliquots of NBSSRM 1571, Orchard Leaves.

Cleaning the Apparatus

The method used to clean the Labconco Model 65000® digestion apparatus and Labconco Model 60300® distillation apparatus is presented on Page 4 of MultiTech (1980) Standard Procedure No. 15.

ATTACHMENT IV.3

DETERMINATION OF PHOSPHORUS CONTENT IN PLANT MATERIALS

Approximately 1-gm of sample is prepared for digestion as described in the first paragraph of Attachment IV.1 (wet ashing). Specific modifications of this general procedure are given in stepwise fashion below:

(1) Initially, add 10 to 15 mL. of 3:2 conc. HNO_3: conc. H_2SO_4 (AR grade) solution to each flask; heat gently (at 130-145°C) until expulsion of NO_2 is nearly complete, and white SO_3 fumes appear. Carefully add 5 mL of conc. HNO_3 and reflux until the SO_3 fumes reappear.

(2) Add 1 mL conc. (AR grade) $HClO_4$ to each flask, and reflux at 190-200°C until dense white perchloric acid fumes fill the flask.

(3) Remove flask(s) from the hot plate and set on an asbestos sheet to cool slightly. Shortly after, add approximately 20 mL DI water and swirl gently so as to put the insoluble silicates, etc., into suspension.

(4) Rinse flask contents through a pre-wetted Whatman No. 40 filter paper, capturing the filtrate in a 100 ml. volumetric flask. The quantitative transfer of soluble P is ensured by washing the insoluble material (in the paper) using several

10-ml. increments Of DI water; these washings are collected (as filtrate) in the volumetric flask.

(5) The filtrate is diluted to standard volume using DI water. The sample-P content can be determined either by ICP or by colorimetry.

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SILVER BOW CREEK REMEDIAL INVESTIGATION
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ATTACHMENT V

QA/QC DATA

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SUMMARY OF PHASE ONE AGRICULTURAL SAMPLES ANALYZED
BY MULTITECH

Site No.	Soils Field/Laboratory Nos.	Vegetation Field/Laboratory Nos.
A10	A10-5/S305	A10-1/V052
A11	A11-6/S306	A10-2/V053
A1	A1-7/S307 A1-8/S308 A1-9/S309	A1/V054
A2	A2-10/S310	A2/V055
A3	A3-11/S311 A3-12/S312 A3-13/S313	A3-1/V056 A3-2/V057
T12	T12-59/S320 T12-60/S321	T12/V060
T13	T13-61/S317 T13-62/S318 T13-63/S319	T13/V058
T14	T14-55/S322	T14/V059
T15	T15-56/S323	T15/V063
T16	T16-57/S324	T16/V062
T17	T17-58/S325 Field Blank/S327	T17/V061 Field Blank/V064
A6	A6-18/S339 A6-19/S340 A6-20/S341	A6-1/V065 A6-2/V066
A7	A7-14/S335 A7-15/S336 A7-16/S337 A7-17/S338	A7/V067

SUMMARY OF PHASE ONE AGRICULTURAL SAMPLES ANALYZED
BY MULTITECH (Continued)

Site No.	Soils Field/Laboratory Nos.	Vegetation Field/Laboratory Nos.
A12	A12-21/S342	A12/V068
	A12-22/S343	
	Duplicate/S362	
	A12-23/S344	
	Duplicate/S363	
A13	A13-98/S328	A13/V069
	A13-99/S329	
	A13-24/S345	
	Duplicate/S364	
	A13-25/S346	
	Duplicate/S365	
	A13-26/S347	
	A13-27/S348	
A9	A9-1/S301	A9/V051
	A9-2/S302	
	A9-3/S303	
	A9-4/S304	
	Field Blank/S300	

QUALITY ASSURANCE TERMINOLOGY

The QA terms pertinent to data accuracy and precision--and cited in Section 2.5.1 of the RI report--are defined below (MultiTech and Stiller and Associates 1985).

Accuracy

Accuracy is defined as the degree of agreement of a measurement with the "true" or accepted value for the measurement. For the purpose of this study the primary assessment of accuracy was the Known Sample Agreement percent, KSA(%), and Spiked Sample Recovery percent, SSR(%), defined as follows:

$$KSA(\%) = \frac{X}{T} \times 100 \qquad (5\text{-}1)$$

where: X = measured value

T = "true" or accepted value

$$SSR\% \qquad \frac{X_2 - (X_1)(D_1)}{(S)(D_2)} \qquad (5\text{-}2)$$

where: X_1 = sample result
X_2 = spiked sample result
D_1 = sample dilution factor
S = spike concentration
D_2 = spike dilution factor

Precision

Precision is defined as the measure of mutual agreement among individual measurements of the same property, usually under prescribed similar conditions.

For the purpose of this study, the Duplicate Sample Agreement percent, DSA(%), and the Replicate Sample Agreement percent, RSA(%) defined by the following equations, were used as the measures of precision:

$$DSA(\%) = \frac{d_1}{(d_1 + d_2)/2} \times 100\% \qquad (5\text{-}3)$$

where: d_1 = first sample result

d_2 = second sample result

$$RSA(\%) = \frac{r_1}{(r_1 + r_2)/2} \times 100\% \qquad (5\text{-}4)$$

where: r_1 = first measurement on sample

r_2 = second measurement on sample

ATTACHMENT V.1

QA/QC DATA FOR SOILS

V.1.1 pH

"Q" Sample Nos.	Contents	Comments
No formal Q (lab. generated) samples, but calibration checks were performed after sample nos. 308, 317, 329, 343, 353, and 368.	Std. pH solutions of 4.0 and 7.0 were used for calibration checks.	--

Lab. Replicate Samples

310	7.98	320	6.19	339	4.62	362	6.43	365	4.69
310D	8.04	320D	6.39	339D	4.94	362D	6.57	365D	4.89
RSA	100	RSA	98	RSA	97	RSA	99	RSA	98

Field Duplicate Samples

328	4.22	343	6.41	344	7.93	345	4.57	346	4.89
329	4.49	362	6.43	363	7.95	364	4.54	365	4.69
DSA	97	DSA	100	DSA	100	DSA	100	DSA	102

V.1.2 Electric Conductivity

"Q" Sample Nos.	Contents	Comments
One "Q" std. was used to check measurement accuracy.	0.01NKCl solution.	Theoretical value = 1413 µmhos, vs. observed value of 1379 µmhos. The KSA = 98%.

Lab. Replicate Samples

µmhos/cm.

310	3192.96	320	862.42	339	302.32	362	350.05	365	1325.98	307	14,532.73
310R	3182.35	320R	869.84	339R	303.38	362R	354.30	365R	1325.98	410	15,593.51*
RSA	100	RSA	100	RSA	100	RSA	99	RSA	100	RSA	96

*Blind split

Field Duplicate Samples

				µmhos/cm.					
328	4760	343	3990	344	1230	345	3650	346	1490
329	1146	362	3300	363	1109	364	3320	365	1250
DSA	161	DSA	109	DSA	105	DSA	105	DSA	91

V.1.3 Mechanical Analyses

"Q" Sample Nos.	Contents	Comments
No formal Q samples, except for the "Calgon Correction Blanks", as noted on the report sheets.	Blank solution was 100 gm(±) Calgon, diluted to 1 L with DI water.	--

Lab Replicate Samples

	% w/w, oven dry		
Sample Nos.	Sand	Silt	Clay
S346	57.1	25.2	17.7
346R	57.7	25.1	17.2
RSA	99	100	101
S314	46.9	42.2	10.9
314R	50.0	40.0	10.0
RSA	97	103	104
S361	21.4	61.7	16.9
361R	22.6	64.3	13.1
RSA	97	98	113
S373	30.5	58.6	10.9
373R	30.7	58.7	10.6
RSA	100	100	101

Field Duplicate Samples

	% w/w, oven dry		
Sample No.s	Sand	Silt	Clay
328	53.3	33.1	13.6
329	52.7	28.4	18.9
DSA	101	108	84
343	49.9	41.8	8.3
362	50.2	42.0	7.8
DSA	98	100	103
344	59.7	32.0	8.3
363	55.5	36.7	7.8
DSA	104	93	103
345	53.2	31.4	15.4
364	49.3	35.0	15.7
DSA	104	95	99
346	57.1	25.2	17.7
365	54.5	37.8	7.7
DSA	102	80	139

V.1.4 Saturation Paste (Alkali/Alkaline Earths)

Instrumental "Q" Samples*

Laboratory I.D.	Ca, KSA	Laboratory I.D.	Ca, SSR	Laboratory I.D.	Ca, RSA
WP1183 #1 (4x)	92	4ml std. #1, 6ml 305 (100x)	93	304/304R	100
WP1183 #1 (4x)	98	2ml std. #1, 8ml 320 (100x)	103	319/319R	98
WP1183 #1 (4x)	98	4ml std. #1, 6ml 336 (10x)	98	335/335R	101
WP1183 #1 (4x)	97	2ml std. #1, 8ml 342 (100x)	108	346/346R	101
WP1183 #1 (4x)	97	4ml std. #1, 6ml 1109	98	Q1109/Q1109R	99
WP1183 #1 (4x)	95	(100x)			

Laboratory I.D.	Mg, KSA	Laboratory I.D.	Mg, SSR	Laboratory I.D.	Mg, RSA
WP1183 #1 (4x)	106	4ml std. #1, 6ml 305 (100x)	104	306/306R	101
WP1183 #1 (4x)	106	2ml std. #1, 8ml 320 (100x)	108	312/312R	101
WP1183 #1 (4x)	106	4ml std. #1, 6ml 336 (10x)	103	325/325R	99
WP1183 #1 (4x)	106	2ml std. #1, 8ml 342 (100x)	108	345/345R	102
WP1183 #1 (4x)	107	4ml std. #1, 6ml 1109	105	364/364R	98
WP1183 #1 (4x)	108	(100x)			

Laboratory I.D.	K, KSA	Laboratory I.D.	K, SSR	Laboratory I.D.	K, RSA
WP1183 #2 (2x)	102	2ml 2ppm K, 8ml 308 (1000x)	106	305/305R	100
WP1183 #2 (2x)	98	2ml 2ppm K, 8ml 321 (100x)	103	317/317R	100
WP1183 #2 (2x)	97	3ml 2ppm K, 7ml 337 (100x)	104	329/329R	101
WP1183 #2 (2x)	98	2ml 2ppm K, 8ml 410 (1000x)	105	347/347R	100
WP1183 #2 (2x)	98				

Laboratory I.D.	Na, KSA	Laboratory I.D.	Na, SSR	Laboratory I.D.	Na, RSA
WP1183 #2 (2x)	105	3ml std. #1, 7ml 310 (1000x)	112	306/306R	100
WP1183 #2 (2x)	105	3ml std. #1, 7ml 313 (1000x)	106	313/313R	99
WP1183 #2 (2x)	104	3ml std. #1, 7ml 339 (10x)	105	328/328R	100
WP1183 #2 (2x)	104	3ml std. #1, 7ml 342 (10x)	104	343/343R	100
WP1183 #2 (2x)	106	3ml std. #1, 7ml 364 (100x)	108	1109/1109R	102
WP1183 #2 (2x)	106	(100x)			

* Dilution factors given in parentheses.

"Q" Sample Nos.	Contents	mg/L (solution) Ca	Mg	K	Na
Q1108	DI HOH, filtered	8.12	2.20	0.352	2.68
Q1109	Blind split from 319	103	20.4	18.1	259
Q1110	Lab. spike (10ml 317 + 4ml 10^3ppm Ca, 1ml 10^3ppm Mg, 1ml 10^3K and 9ml 10^3 Na)	199	48.3	45.2	415
Q1111	Field blank, S327	1.17	0.457	0.136	0.740

Sample Nos.	Ca	Mg	K	Na
	mg/L			
319	97.1	19.4	17.7	267
Q1109	103	20.4	18.1	259
RSA	97	97	99	102
317 (sample)	86.0	18.0	12.4	188
Q1110 (spike)	199	48.3	45.2	415
SSR	103	103	101	94

Field Duplicate Samples

Sample Nos.	Ca	Mg	K	Na
	mg/L			
328	570	297	50.9	74.8
329	130	45.1	25.9	24.8
DSA	163	174	133	150
343	44.7	12.7	24.8	4.8
362	37.5	10.1	25.2	3.9
DSA	109	111	99	110
344	209	58	25.8	14.3
363	179	53	24.4	12.9
DSA	108	104	103	105
345	586	172	63.8	43.4
364	558	148	52.1	33.4
DSA	102	108	110	113
346	208	63	30.1	20.4
365	164	48.8	25.2	16.7
DSA	112	113	109	110

V.1.5 "Plant Available" Heavy Metals (Excluding As)

Instrumental "Q" Samples

- KSA

Laboratory I.D.	Elements (%) Cd	Cu	Fe	Mn	Pb	Zn
WP284 #2 (20x dilution)	113	100	102	98	101	102
WP284 #2 (20x)	114	102	101	101	97	102
WP284 #2 (20x)	115	101	99	98	94	101
WP284 #2 (20x)	106	100	98	95	100	98
WP284 #2 (20x)	ND*	101	ND	103	ND	ND
WP284 #2 (20x)	111	ND	103	ND	97	103

*ND = Not determined (no analysis performed on sample)

- SSR

Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
2#1STD8S303P	75	91	90	86	ND	83
1#1STD9Q1018	ND	80	90	86	ND	75
2#1STD8S323P	83	98	88	85	79	81
1#1; 9S339P	ND	92	87	89	ND	79
1#1; 9S347P	ND	87	ND	82	ND	ND
1#1; 9S410P	78	ND	80	ND	79	82
1#1; 4S304P	ND	ND	ND	ND	76	ND
2#1; 8S311P	80	ND	ND	ND	76	ND
2#3; 8S336P	80	ND	ND	ND	86	ND

- RSA

Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
R-S307P	101	100	98	100	ND	98
R-S312P (10x dilution)	ND	99	100	99	ND	99
R-S322P	98	100	98	98	97	97
R-S336P	ND	101	101	100	ND	102
R-S347P	ND	99	ND	96	ND	ND
R-S365P	100	ND	90	ND	100	98
R-S306P	ND	ND	ND	ND	97	ND
R-S310P	96	ND	ND	ND	96	ND
R-S339P	101	ND	ND	ND	101	ND

"Q" Sample Nos.	Contents	Elements (mg/L of extract) Cd	Cu	Fe	Mn	Pb	Zn
Q1017	DTPA Reagent blank	<0.005	0.191	0.105	<0.046	<0.067	0.038
Q1018	NH_4OAc Reagent blank	<0.005	<0.027	<0.028	<0.031	<0.109	<0.077
Q1019	Field blank S300	<0.005	<0.027	<0.028	<0.031	<0.109	<0.065
Q1020	1ml. 50ppm Cu^{+2} in S322	0.485	9.63	0.205	39.5	2.51	9.72
Q1021	EPA Municipal sludge	0.595	3.30	6.23	4.82	0.985	28.3
Q1022	Blind split of S324 extract	0.653	32.8	0.369	37.5	7.49	16.2
Q1023	Lab blank, DI HOH	<0.011	<0.034	<0.063	<0.034	<1.131	<0.046
Q1024	Lab blank, DI HOH	<0.011	0.050	0.519	<0.034	<1.131	<0.046

SSR for Q1020, Cu = 84
RSAs for Q1022(D1), S324(D2): Cd, 102; Cu, 100; Fe, 94; Mn, 97; Pb, 106; Zn, 102.

Lab. Replicate Samples

Sample Nos.	Cd	Cu	Fe	Mn	Pb	Zn
	mg/L of extract					
307	0.160	3.81	3.70	2.65	1.05	6.24
307R	0.162	3.78	3.55	2.64	ND*	5.97
RSA	99	100	102	100	--	102
307	0.160	3.81	3.70	2.65	1.05	6.24
410 (BD)	0.160	4.16	3.56	2.33	0.91	6.13
DSA	100	96	102	106	107	101
312	1.16	11.5	7.89	2.40	14.3	81.7
312R	ND	11.3	8.62	2.63	ND	79.8
RSA	--	101	96	95	--	101
322	0.497	10.5	0.374	41.3	2.59	8.82
322R	0.478	10.5	0.360	39.6	2.46	8.35
RSA	102	100	102	102	103	103
336	0.851	53.4	0.625	24.2	12.5	43.3
336R	ND	54.9	0.639	24.4	ND	44.6
RSA	--	99	99	100	--	99
347	0.090	3.51	0.572	1.29	<0.131	8.28
347R	ND	3.43	ND	1.20	ND	ND
RSA	--	101	--	104	--	--
365	0.367	242	0.165	45.3	0.448	44.3
365R	0.367	ND	0.141	ND	0.445	42.7
RSA	100	--	108	--	100	102
306	1.22	201	0.328	4.32	0.321	257
306R	ND	ND	ND	ND	0.304	ND
RSA	--	--	--	--	103	--
310	0.717	63.8	6.54	6.76	32.1	18.9
310R	0.669	ND	ND	ND	29.8	ND
RSA	104	--	--	--	104	--
339	0.320	9.10	0.898	8.06	3.59	6.42
339R	0.328	ND	ND	ND	3.67	ND
RSA	99	--	--	--	99	--

* ND = Not determined (no analysis performed on sample).

Field Duplicate Samples

Sample Nos.	mg/L of extract Cd	Cu	Fe	Mn	Pb	Zn
328	0.633	376	1.34	115	0.351	106.
329	0.357	218	0.688	52.6	1.16	34.0
DSA	128	127	132	137	46	151
343	0.041	0.745	<0.056	1.95	0.023	0.477
362 (BD)	0.025	0.492	<0.063	0.876	<0.131	0.353
DSA	124	120	--	138	—	115
344	0.004	0.788	1.86	1.82	0.192	0.158
363	<0.011	0.831	0.926	0.926	0.162	0.094
DSA	--	97	134	133	108	125
345	0.577	380	0.655	86.8	0.239	87.2
364L	0.501	341	0.366	79.3	0.461	82.1
DSA	107	105	128	105	68	103
346	0.445	267	0.167	51.5	0.402	52.5
365	0.367	242	0.153	45.3	0.446	43.5
DSA	110	105	104	106	95	109

V.1.6 Acid Extractable ("Total") Heavy Metals (Excluding As)

Instrumental "Q" Samples

• KSA

Laboratory I.D.	Elements (%) Cd	Cu	Fe	Mn	Pb	Zn
STA 0029 (5x)*	99	103	110	106	104	104
STA 0029 (5x)	102	101	111	105	108	103
STA 0029 (5x)	95	97	105	101	102	97
STA 0029 (5x)	99	97	109	102	102	94
STA 0029 (5x)	102	101	115	107	107	103
STA 0029 (5x)	93	97	104	101	100	95
STA 0029 (5x)	97	95	104	99	98	94

• SSR

Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
2#1STD8S302	94	93	108	97	94	95
2#1STD8S317	87	85	89	81	86	85
2#1STD8S336	98	105	108	115	98	100
2#1STD8S342	94	102	104	88	87	93
2#1STD8Q1047	90	93	89	88	90	86

* Dilution factors given in parentheses.

· RSA	Elements (%)					
Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
	97	98	97	98	97	97
R-S301						
R-S312	102	98	100	99	98	100
R-S329	98	101	100	102	104	100
R-S346	100	102	103	103	104	102
R-S364	100	101	102	101	99	99

"Q" Sample		mg/L of extracts					
Nos.	Contents	Cd	Cu	Fe	Mn	Pb	Zn
Q1043	Field Blank, 20 ml. of S300	<0.008	<0.260	<0.396	<0.057	<0.174	<0.085
Q1044	Reagent blank	<0.008	<0.260	<0.396	<0.057	<0.174	<0.085
Q1045	0.1 ml 500 ppm Zn in S308	<0.008	0.298	202	5.27	0.265	1.63
Q1046	NBS.Estuarine Sediment(AD)	0.008	0.306	446	4.06	0.527	2.17
Q1047	Split digest of S307	0.043	0.661	132	7.17	0.298	1.08
Q1048	Lab. blank, DI HOH	<0.008	<0.260	<0.396	<0.057	<0.174	<0.085
Q1049	Lab. blank, DI HOH	<0.008	<0.260	<0.396	<0.057	<0.174	<0.085
Q1050	Blind Split(S410=S307)	0.036	0.761	233	8.22	0.440	1.44
Q1148	NBS Estuarine Sediment (AD)	<0.006	0.284	286	2.22	0.276	1.05
Q1149	NBS Estuarine Sediment (AD)	<0.006	0.308	270	2.27	0.303	1.12
Q1150	S329(AD)	0.090	16.8	207	6.44	2.67	4.32

	Cd	Cu	Fe	Mn	Pb	Zn
·KSA						
Q1046(Air dry)	111	85	67	54	94	78
Q1148(Air dry)	--*	158	85	59	98	76
Q1149(Air dry)	--*	167	81	61	107	81
·SSR for Q1045	ND**	ND	ND	ND	ND	77
·RSA for Q1047 and S307	104	78	95	97	89	93
·RSA for S307 and Q1050	105	115	77	96	91	93
·RSA for S329 and Q1150	124	106	101	105	100	106

* Below MDL (<0.6 µg/g)

** ND = Not determinded (no analysis performed on sample).

Lab Replicate Samples

	mg/L of extract					
Sample Nos.	Cd	Cu	Fe	Mn	Pb	Zn
S301	0.159	41.3	303	19.6	3.32	23.7
301R	0.168	42.7	320	20.1	3.50	25.1
RSA	97	98	97	99	97	97
S312	0.200	24.6	223	37.5	9.72	37.3
312R	0.209	23.7	224	37.1	9.30	37.4
RSA	98	102	100	101	102	100
S329	0.296	37.6	416	13.8	5.04	9.65
329R	0.285	38.1	416	14.4	5.46	9.69
RSA	102	99	100	98	96	100

	mg/L of extract					
Sample Nos.	Cd	Cu	Fe	Mn	Pb	Zn
S346	0.122	31.2	234	11.4	1.51	8.02
346R	0.121	32.2	247	12.0	1.62	8.34
RSA	100	98	97	97	96	98
S364	0.355	51.1	435	10.2	5.19	11.9
364R	0.354	51.7	448	10.4	5.07	11.6
RSA	100	99	99	99	101	101

Field Duplicate Samples

	mg/L of extract					
Sample Nos.	Cd	Cu	Fe	Mn	Pb	Zn
S328	0.351	51.1	412	12.5	6.01	12.9
329	0.296	37.6	416	13.8	5.04	9.65
DSA	108	115	100	95	109	114
S343	0.029	2.04	259	13.2	0.398	1.40
362	0.017	1.92	418	12.9	0.584	1.60
DSA	126	103	77	101	81	93
S344	<0.008	0.842	247	10.6	0.393	1.18
363	<0.008	0.772	423	15.1	0.641	1.40
DSA	--	104	74	82	76	91
S345	0.186	55.2	276	10.3	4.49	10.8
364	0.355	51.1	435	10.2	5.19	11.9
DSA	69	104	78	100	93	95
346	0.121	32.2	247	12.0	1.62	8.34
365	0.149	33.0	421	11.4	2.47	7.88
DSA	90	99	74	103	79	103

V.1.7 "Plant Available" Arsenic (by Halvorson Method)

Instrumental "Q" Samples

- KSA

Laboratory I.D.	As
WP284#1(.013x)*	112
WP284#1(.013x)	96
WP284#1(.013x)	111
WP284#1(.013x)	93
WP284#1(.013x)	100

* Dilution factor.

• SSR

Laboratory I.D.	As
2#1STD8S301A	75
2#1STD8S312A	110
2#1STD8S322A	86
2#1STD8S335A	107
2#1STD8S346A	93

• RSA

Laboratory I.D.	As
R-S303A	98
R-S311A	108
R-S325A	103
R-S339A	106
R-S364A	104

"Q" Sample

Nos.	Contents	As, mg/L of extract
Q1025	Field Blank, S327	<0.291
Q1026	Reagent Blank	<0.291
Q1027	0.1ml. 1000ppm As in S342	5.94
Q1028	EPA Municipal Sludge	1.46
Q1029	Split extract from S348	1.04
Q1030	Lab. Blank, DI HOH	<0.349
Q1031	Lab. Blank, DI HOH	<0.349
Q1151	EPA Municipal Sludge #1691(AD)	1.62
Q1152	NBS Estuarine Sediment (OD)	0.76
Q1153	1.0 ml. of 1000ppm As in 16 ml. of S342 filtrate.	17.7
Q1154	~4 gms. S342.	4.46

	As
•KSA	
Q1028	172
Q1151	183
Q1152	131
•SSR	
Q1027	53
Q1153	28
•RSA	
Q1029 and S348	106
Q1154 and S342	89

Comment

Q1028 and Q1151 values of 29.2 and 31.1 µg/g vs. US.EPA $\bar{x}$ = 17.0 µg/g(0-88.9 µg/g, 95% confidence interval). Q1152 = 15.2 µg/g vs. NBS=11.6±1.3 µg/g.

Lab. Replicate Samples

Sample Nos.	As, mg/L of extract
S303A	27.7
303A(R)	26.4
RSA	102

Sample Nos.	As, mg/L of extract
S311A	30.0
311A(R)	35.2
RSA	92
S325A	5.59
325A(R)	5.87
RSA	98
S339A	6.74
339A(R)	7.57
RSA	94
S364A	18.6
364A(R)	20.1
RSA	96

Field Duplicate Samples

Sample Nos.	As, mg/L of extract
S328	29.4
329	23.4
DSA	111
S343	2.46
362	2.21
DSA	105
S344	0.530
363	0.544
DSA	99
S345	21.5
364	18.6
DSA	107
S346	7.94
365	9.43
DSA	91

V.1.8 Aqueous Arsenic and Phosphorus Ions Analysis

V.1.8.1 Arsenic

Instrumental "Q" Samples

- KSA

Laboratory I.D.	As
WP284#2(20x)*	106
WP284#2(20x)	101
WP284#2(20x)	102
WP284#2(20x)	100
WP284#2(20x)	101
WP284#2(20x)	94

* Dilution factor

- SSR

Laboratory I.D.	As
3#1STB7BS304	94
3#1STB7BS322	93
3#1STB7BS339	93
3#1STB7BS364	92
1#1STD90LS310	97

- RSA

Laboratory I.D.	As
R-Bray S305	103
R-Bray S324	101
R-Bray S340	104
R-Bray S365	101
R-Olsen S323	97

"Q" Sample

Nos.	Contents	As, mg/L of extract
Q1032	Bray Reagent Blank	<0.073
Q1033	Olsen Reagent Blank	<0.073
Q1034	Field Blank, 5ml. of S327	<0.073
Q1035	1 ml. 100ppm P to S313(B)	0.108
Q1036	1 ml. 100ppm P to S308(0)	0.124
Q1037	Lab. duplicate (S410=S307)	0.444
Q1038	Split extract of S339(B)	2.98
Q1039	Split extract of S348(0)	0.076
Q1040	3.5 ml. 100ppm P, 0.5 ml. 100 ppm As and 32 ml. S329(B).	4.63
Q1041	4.5 ml. of 100ppm P, 0.5 ml. 100ppm As and 45 ml. S348(0).	2.03
Q1042	Lab. blank, DI HOH	<0.073

·KSA --see instrumental KSAs

·SSR
  Q1040 = 105
  Q1041 = 176

·RSA
  S308 and Q1036 = 114
  S339 and Q1038 = 101

Lab Replicate Samples

Sample Nos.	As, mg/L of extract
S305	0.564
305R	0.602
RSA	97
S324	2.87
324R	2.93
RSA	99
S340	0.770
340R	0.841
RSA	96
S323	1.54
323R	1.43
RSA	104

Field Duplicate Samples

Sample Nos.	As, mg/L of extract
S328	4.73
329	3.57
DSA	114
S343	0.432
362	0.427
DSA	101
S344	<0.073
363	<0.073
DSA	--
S345	4.48
364	4.04
DSA	105
S346	1.77
365	2.76
DSA	78

V.1.8.2 Phosphorus

Instrumental "Q" Samples

Calibration curves were fitted to data generated from use of known concentrations of P; the correlation (r) values were ≥ 0.999.

"Q" Sample Nos.	Contents	P, mg/L
Q1032	Bray Reagent blank	-0.086
Q1033	Olsen Reagent blank	0.722
Q1034	Field blank, 5ml. of S327	-0.066
Q1035	1ml. 100ppm P to S313(B)	0.560
Q1036	1ml. 100ppm P to S308(0)	12.659
Q1037	Lab. duplicate (S410=S307)	2.436
Q1038	Split extract of S339(B)	9.867
Q1039	Split extract of S348(0)	0.782
Q1040	3.5 ml. 100ppm P, 0.5ml. 100 ppm As and 32 ml. S329(B)	10.932
Q1041	4.5 ml. 100ppm P, 0.5ml. 100 ppm As and 45 ml. S348(0)	10.009
Q1042	Lab. blank, DI HOH	-0.086

·KSA--see instrumental "Q" samples comment

·SSR
Q1035=17
Q1036=82
Q1040=145
Q1041=106

·RSA
S307 and Q1037 = 101
S339 and Q1038 = 98
S348 and Q1039 = 89

Lab. Replicate Samples

- Bray Extract		- Olsen Extract	
Sample Nos.	P, µg/g of soil	Sample Nos.	P, µg/g of soil
S324	24.96	S309	1.43
324R	36.51	309R	1.22
RSA	81	RSA	108
S336	27.12		
336R	27.25		
RSA	98		
S364	25.12		
364R	24.27		
RSA	102		

Field Duplicate Samples

- Bray Extract		- Olsen Extract	
Sample Nos.	P, µg/g of soil	Sample Nos.	P, µg/g of soil
S328	23.55	S344	2.248
329	20.32	363	4.538
DSA	107	DSA	66
S343	20.59		
362	20.69		
DSA	100		
S345	27.23		
365	25.12		
DSA	104		
S346	20.39		
365	20.32		
DSA	100		

V.1.9 Nitrogen (Water Extractable)

Instrumental "Q" Samples

Calibration curves were fitted to data generated from use of known concentrations of N; the correlation (r) values were $\geq$ 0.9996.

"Q" Sample Nos.	Contents	N, mg/L
Q1155	0.25ml. 1000 ppm N and 20 gms. S335	43.1
Q1156	Reagent Blank, 40 ml. DI water	2.6
Q1157	Blind split, S410=S307	14.1

- KSA--see instrumental "Q" Samples comment

- SSR
  S301+.250ml. 1000 mg/LN = 106
  S318+.250ml. 1000 mg/LN = 101

- RSA
  S307 and Q1157 = 81

Lab Replicate Samples

See above RSA value.

Field Duplicate Samples

Sample Nos.	N, µg/g of soil	Sample Nos.	N, µg/g of soil
S328	24.8	S345	14.6
329	3.2	S364	6.5
DSA	177	DSA	138
S343	1.2	S346	5.9
362	1.0	S365	3.3
DSA	109	DSA	128
S344	3.1		
363	2.7		
DSA	107		

V.1.10 Sulfate Ion

Instrumental "Q" Samples

The calibration curve was constructed manually, using SO_4^{-2} concentrations (mg/L) as the "x" and corresponding absorbance values as the "y". Prior to analyzing the unknowns, a 25 mg/L standard read 25.8 mg/L; this yields a KSA of 103%.

"Q" Sample Nos.	Contents	SO_4, mg/L
Q1142	Reagent Blank	0.0
Q1143	20 ml. 100 ppm std. to 20 gms. of S301	258
Q1144	Split extract from S364	<5
Q1145	15 ml. of 30 ppm std. to 10 ml. of extract from S319	36.8
Q1146	15 ml. of 50 ppm std. to 10 ml. of extract from S341	32.9
Q1147	Split extract from S344	21.1

- KSA--see instrumental "Q" comment

- SSR
  - Q1143=84
  - Q1145=107
  - Q1146=110

- RSA
  - Q1144=Not determined (both values <5 µg/g soil)
  - Q1147=97

Lab Replicate Samples

Sample Nos.	SO_4 µg/g
S307	6750
410	6250
RSA	104

Field Duplicate Samples

Sample Nos.	SO_4, µg/g of soil	Sample Nos.	SO_4, µg/g of soil
S328	3420	S345	3790
329	70.3	S364	3240
DSA	196	DSA	108
S343	<5	S346	66.3
362	<5	S365	53.7
DSA	--	DSA	110
S344	22.6		
363	13.2		
DSA	126		

V.1.11 Total Sulfur

Instrumental "Q" Samples

The absorbance values for the standards were entered into a third order regression (software) program, thus generating the calibration curve; the coefficient of determination (r^2)=0.9987. Concentration values for the unknowns were interpolated from this curve, using the respective absorbance readings.

"Q" Sample Nos.	Contents	SO_4,mg/L
Q1176	Reagent Blank, 4 gms. of Eschka's mixture	4.38
Q1177	Blind split, S410 = S307	66.27
Q1178	Estuarine sediment, 1 gm. (NBS SRM)	235.76
Q1179	Split extract from S325	8.64
Q1180	0.1 ml. of 2500 mg/L SO_4^{-2} + 24.9 ml. S343	16.86

·KSA
Q1178=82

·SSR
Q1180=109

·RSA
S307 and Q1177=101
S325 and Q1179=96

Lab Replicate Samples

Sample Nos.	%S
S302	0.1280
302R	0.0924
RSA	116
S312	0.2450
312R	0.2167
RSA	106
S325	0.0330
325R	0.0232
RSA	117
S343	0.1000
343R	0.0162
RSA	172

Field Duplicate Samples

Sample Nos.	%S	Sample Nos.	%S
S328	0.2150	S345	0.2390
329	0.0580	S364	0.2200
DSA	158	DSA	104
S343	0.1000	S346	0.0330
362	0.0270	S365	0.0010
DSA	157	DSA	194
S344	0.0200		
363	0.0040		
DSA	167		

ATTACHMENT V.2

QA/QC DATA FOR PLANT MATERIALS

V.2.1 Acid Extractable Heavy Metals

Instrumental "Q" Samples (ICP)

- KSA

Laboratory I.D.	Elements (%) Cd	Cu	Fe	Mn	Pb	Zn
Q916	101	100	97	98	105	102
Q916	102	99	96	96	104	100
Q916	103	96	97	97	104	98
Q916	101	98	101	101	108	102

- SSR

Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
2#1STD8V057	94	98	94	94	89	99
2#1STD8V063	99	103	104	101	96	105
1#1STD9Q1056	97	101	97	96	109	102

- RSA

Laboratory I.D.	Cd	Cu	Fe	Mn	Pb	Zn
R-V056	92	100	101	101	98	102
R-V062	94	103	103	100	<MDL*	100
R-Q1054	114	98	99	98	101	101

* MDL = Method Detection Limit.

Instrumental "Q" Samples (HG/AAS for As)

- KSA

Laboratory ID	As
WS378#13	95
WS378#13	100
WS378#13	101

- SSR

Laboratory ID	As
S-V057	90
S-V063	109
S-Q1053	100

- RSA

Laboratory ID	As
D-V056(10x)	96
D-V066(2x)	103
D-Q1059 (2x)	102

* Dilution factors.

"Q" Sample Nos.	Contents	Elements[a] As	Cd	Cu	Fe	Mn	Pb	Zn
Q1051*	Field blank, V064	<0.0088	<0.004	<0.006	3.06[b]	0.015	<0.090	0.042
Q1052*	Reagent blank	<0.0088	<0.004	<0.006	0.107[b]	<0.007	<0.090	0.010
Q1053	0.1ml. 1000ppm Cu to V054 digestate.	0.953	<0.2	121	111	23.8	77.5	24.6
Q1054	NBS Orchard Leaves (OD)	9.939	0.208	11.031	377.77	69.52	29.56	24.14
Q1055	NBS Citrus Leaves (OD)	3.382	<MDL[c]	15.59	1008[b]	20.04	11.14	25.03
Q1056	Blind split from V068	<0.440	<0.2	5.60	112	26.2	<4.5	23.2
Q1057	Split digest from V052	<0.440	<0.2	6.35	46.8	34.9	<4.5	29.4
Q1058*	Lab. blank, 20 ml. DI HOH	<0.0088	<0.004	<0.006	0.341[b]	<0.007	<0.090	<0.007
Q1059	NBS Citrus Leaves (OD)	0.0695	<0.2	14.4	72.5	16.4	11.0	23.4

Notes: a) Samples with asterisks (*) are in mg/L, while others are in µg/g.
b) Known contamination (occurred during ashing).
c) MDL = Method Detection Limit.

	Elements (%) As	Cd	Cu	Fe	Mn	Pb	Zn
• KSA							
Q1054	100	131	96	111	87	79	98
Q1055	104	--	97	--	93	91	93
Q1059	106	--	96	92	86	93	92
• SSR							
Q1053	--	--	91	--	--	--	--
• RSA							
V068 and Q1056	--	--	107	146	105	--	100
V052 and Q1057	--	--	99	99	98	--	99

Lab. Replicates
-See above RSA values.

Field Duplicate Samples

Sample Nos.	Elements(µg/g) As	Cd	Cu	Fe	Mn	Pb	Zn
V065	1.894	<0.2	23.0	191	37.8	46.7	33.8
V066	2.746	0.4	9.15	234	43.6	7.80	33.4
DSA	82	--	143	90	93	171	101

V.2.2 Kjeldahl Nitrogen

Instrumental "Q" Samples

The only pertinent sample was the HCl titrant, which was standardized to 0.0899 N using 0.1N NaOH solution.

"Q" Sample Nos.	Contents	%N
Q1133	10 ml. V064 (DI water)	0.000
Q1134	Reagent Blank	0.000
Q1135	0.5 ml of WP 284 #6 to V052 digestate	1.94
Q1136	NBS Orchard Leaves (#1)	2.58
Q1137	Blind split from V068 (Q5)	1.09
Q1138	Split digest from V068	1.41
Q1139	Lab. blank, 10 ml. DI water	0.000
Q1140	0.5 ml. of WP284#6 to V051 digestate	2.59
Q1141	NBS Orchard Leaves (#2)	2.52

- KSA
  - Q1136 = 99
  - Q1141 = 97

- SSR
  - Q1135 = 57
  - Q1140 = 66

- RSA
  - Q1137 = 117
  - Q1138 = 104

Lab Replicates

- See above RSA values

Field Duplicate Samples

Sample Nos.	%N
V065	1.08
V066	1.34
DSA	89

V.2.3 Phosphorus

Instrumental "Q" Samples (ICP)

- KSA

Laboratory I.D.	P
15P; 1 Cu	96
15P; 1 Cu	92

- SSR

Laboratory I.D.	P
1;300;9V063	113
1;300;9V051	75

- RSA

Laboratory I.D.	P
R-V068	104

"Q" Sample Nos.	Contents	Concentration[a]
Q1169*	Field Blank, 20 ml. V064	<0.158
Q1170*	Reagent Blank	<0.158
Q1171	5ml. 100 ppm P to V052 digestate	1420
Q1172	NBS Orchard Leaves (OD)	1593
Q1173	NBS Citrus Leaves (OD)	1209
Q1174	Blind split from V068 (Q5)	1610
Q1175	Replicate from V052	1340

Note: a) Samples with asterisks (*) are in mg/L, while others are in µg/g.

- KSA
  - Q1172 = 76
  - Q1173 = 93

- SSR
  - Q1171 = 93

- RSA
  - Q1174 = 115
  - Q1175 = 105

Lab Replicates
-See above RSA values.

Field Duplicate Samples

Sample Nos.	P, µg/g
V065	1200
V066	1410
DSA	92

V.2.4 Sulfur

Instrumental "Q" Samples
The absorbance values for the standards were entered into a third order regression (software) program, thus generating the calibration curve; the coefficient of determination (r^2) = 0.9987. Concentration values for the unknowns were interpolated from this curve, using the respective absorbance readings.

"Q" Sample Nos.	Contents	SO_4, mg/L
Q1181	Reagent Blank, 4 gms. of Eschka's mixture	5.03
Q1182	0.1 ml. 2500 mg/L SO_4^{-2} + 24.9 ml. V055	18.98
Q1183	Citrus Leaves (NBS SRM)	16.58
Q1184	Blind split, "Q5" = V068	18.20
Q1185	Split extract from V066	27.43
Q1186	DI water blank	0.80
Q1187	Citrus Leaves (NBS SRM)	15.22

- KSA
  Q1182 = 71
  Q1187 = 65

- SSR
  Q1182 = 37

- RSA
  V068 and Q1184 = 38
  V066 and Q1185 = 98

Lab. Replicates
See the RSA values, above.

Field Duplicates

Sample Nos.	%S
V065	0.0929
V066	0.1066
DSA	93

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SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT VI

CRITERIA USED IN EVALUATING THE LABORATORY DATA

VI.1 SOILS
VI.2 PLANT MATERIALS

MultiTech

ATTACHMENT VI.1
SOILS CRITERIA

HEAVY METALS

VI.1.1 Table 4.5-7 of the Work Plan (MultiTech and Stiller and Associates 1984a)

TABLE 4.5-7.--ESTIMATED RANGE (FROM LITERATURE SEARCH) OF VALUES FOR SELECTED PARAMETERS WITHIN THE SURFACE FOOT OF UNCULTIVATED FLOODPLAIN-LOW TERRACE SOIL, DEER LODGE VALLEY, MONTANA

Category	Parameter[a]	Expected Range	Elevated Condition
Non-elemental, but plant nutrient-related	pH	6.0-8.0	<5.0, >8.5
	Redox potential (E_h)	250-500	<100, >600
Vascular plant macro-nutrients[b]	Calcium (Ca)	65-850	>10000
	Magnesium (Mg)	15-140	>2000
	Total Kjeldahl Nitrogen (N)	0.06-0.6	>1.5
	Phosphorus (HPO_4^{-2})	0.2-2.0	>3.0
	Potassium (K)	40-155	>200
	Sulfur (SO_4^{-2})	2-100	>200
Vascular plant micro-nutrients[b]	Boron (B)	0.5-4.5	>4.5
	Cobalt (Co)	0.01-0.15	>0.3
	Copper (Cu)	0.1-5.0	>10.0
	Iron (Fe)	5-15	>25
	Manganese (Mn)	0.2-20	>35
	Molybdenum (Mo)	0.01-0.30	>1.0
	Zinc (Zn)	0.05-4.5	>10
Potentially biohazardous elements (e.g., to vascular plants)[b]	Aluminum (Al)	200-2000	>3500
	Arsenic (As)	0.02-0.20	>0.40
	Cadmium (Cd)	0.005-0.15	>0.20
	Chromium (Cr)	0.001-0.01	>0.20
	Fluorine (F^-)	0.05-2.50	>2.50
	Lead (Pb)	0.01-3.5	>5.0
	Mercury (Hg)	0.001-0.015	>0.025
	Nickel (Ni)	0.02-0.50	>0.75
	Selenium (Se)	0.005-0.50	>0.50
	Vanadium (V)	0.01-0.30	>1.0

Notes: (a) pH reported in standard units, E_h in millivolts (corrected to 25°C), total micro-Kjeldahl nitrogen in weight-percent, and all other parameters in µg/gm (ppm) concentrations.
(b) "Plant-available" estimates from -2 mm mesh soil fraction, using sodium diamine pentacetate solution or in ammonium acetate (pH ≈ 6) solution.

Sources: Bohn et al. 1979, Brady 1974, Berry and Wallace 1974, Chaney 1983, Dvorak et al. 1978, Garrels and Christ 1965, Lewis 1978, Lisk 1972, Nortvedt et al. 1972, MultiTech 1984.

VI.1.2 Expected (Geochemical Background) Levels, taken from Pendias and Pendias (1984)

CATEGORY	ELEMENT (TOTAL, PPM, DRY WEIGHT)[a]						
	As	Cd	Cu	Fe	Mn	Pb	Zn
• Soils formed on volcanic rocks.	2-25 (7)	0.20-1.61 (-)	10-150 (41)	15,000-25,000 (-)	600-2000 (-)	10-45 (22)	30-116 (78)
• Soils formed on granitic rocks.	2-22 (8)	0.20-2.0 (-)	5-70 (27)	15,000-25,000 (-)	350-1250 (-)	15-50 (25)	20-125 (66)

Note: (a) Represent probable concentration range per element, with probable average value given in parentheses, if known.

VI.1.3 Preliminary Phytotoxicity Criteria

CATEGORY	ELEMENT (PPM)[a]						
	As	Cd	Cu	Fe	Mn	Pb	Zn
• Total (Dollhopf et al. 1986)[a]	100[b]	100[b]	NG	NG	NG	1000[c]	500[b]
• Extractable (Dollhopf et al. 1986)[b,d]	50[b]	30[b]	NG	NG	NG	500[e]	60[c]
• Extractable (taken from Table 2 in Schafer 1979)	NG	>1	>40	NG	>60	>20	>40

Notes:

(a) The phytotoxicity data referenced by Dollhopf et al. (1986) may not be directly applicable to the SBC site. However, they were used because the E. Helena Smelter RI study was the nearest CERCLA site where such assessment criteria development had been attempted. Efforts to determine phytotoxicity based on total elemental concentrations are rarely successful. Where statistical relationships between total and plant element levels have been established, great care must be taken to insure that the relationship is only interpreted for the geologic, climatic, and edaphic setting where it was developed.

(b) As quoted from Dollhopf et al. (1986): "Support of scientific literature allows a high degree of confidence that this value will adversely affect crop yield of most species under all soil conditions".

(c) As quoted from Dollhopf et al. (1986): "It is probable that levels in excess of this value will result in reduced crop yields, but scientific literature is relatively less conclusive".

(d) DTPA extractant used for Cd, Pb, and Zn, while HCl extractant used for As.

(e) As quoted from Dollhopf et al. (1986): "This level is considered safe. Scientific literature could not be found where an extractable Pb level caused a crop yield reduction".

VI.1.4 pH (Brady 1974)

Soil Reaction: The degree of acidity or alkalinity of a soil, usually expressed as a pH value.

Extremely acid	Below 4.5
Very strongly acid	4.5-5.0
Strongly acid	5.1-5.5
Medium acid	5.6-6.0
Slightly acid	6.1-6.5
Neutral	6.6-7.3
Mildly alkaline	7.4-7.8
Moderately alkaline	7.9-8.4
Strongly alkaline	8.5-9.0
Very strongly alkaline	9.1 and higher

VI.1.5 Salinity and Sodicity Hazards (MSU Cooperative Extension Service, undated)

Soil Condition	ESP (%)	SAR*	EC (mmhos/cm)
Sodium Hazard			
low	0-5	0-4	-----
medium	5-15	4-12	-----
high	>15	>12	-----
Salinity Hazard			
None	-----	-----	0-2
Slight	-----	-----	2-4
Moderate	-----	-----	4-8
High	-----	-----	8-16
Very High	-----	-----	>16

* Sodium adsorption ratio

VI.1.6 Nitrogen, Potassium, and Phosphorus

·Nitrogen

Parts per million N was converted to lbs./acre N using the following formula:

$$\text{lbs./acre N} = \text{ppm N} * \frac{\text{sample depth (in.)}}{3}$$

The MSU Fertilizer Guides, specific to the crop sampled at a given site, were then consulted to assess apparent adequacy of the nitrogen value measured.

· Potassium

Rating*	ppm
Very Low	0-75
Low	75-125
Medium	125-250
High	>250

*Crop-specific ratings, presented in the Fertilizer Guides were also consulted prior to arriving at the conclusions given in the report.

· Phosphorus

Comparison of Olsen and Bray phosphorus soil tests.

Bray	Olsen	Rating
ppm	ppm	
0-30	0-8	Very Low
30-50	8-12	Low
50-75	12-16	Medium
>75	>16	High

ATTACHMENT VI.2
PLANT MATERIALS CRITERIA

HEAVY METALS

VI.2.1 Table 4.5-8 of the Work Plan (MultiTech and Stiller and Associates 1984a)

TABLE 4.5-8.--ESTIMATED BACKGROUND AND ELEVATED ELEMENTAL CONCENTRATIONS IN NATIVE AND CULTIVATED VEGETATION PRESENT WITHIN THE STUDY AREA

Element	"Background"(a)	"Elevated"(b)
Arsenic (As)	0.05 - 1.5	> 2.5
Beryllium (Be)	0.01 - 0.10	> 0.25
Boron (B)	3 - 8	> 50
Calcium (Ca)	1800 - 36,000	> 45,000
Cadmium (Cd)	0.01 - 0.75	> 3.5
Chromium (Cr)	0.05 - 0.5	> 2.0
Cobolt (Co)	0.02 - 0.35	> 2.5
Copper (Cu)	8 - 16	> 20
Fluorine (F)	1.5 - 20	> 45
Iron (Fe)	80 - 240	> 350
Lead (Pb)	0.5 - 15	> 45
Magnesium (Mg)	1200 - 2000	> 4,000
Manganese (Mn)	20 - 50	> 500
Mercury (Hg)	0.001- 0.025	> 0.05
Molybdenum (Mo)	0.5 - 2.0	> 4
Nickel (Ni)	0.1 - 4.0	> 5
Nitrogen (N)	9600 - 19,200	--(c)
Phosphorous (P)	500 - 3000	--(c)
Potassium (K)	7500 - 25,000	--(c)
Selenium (Se)	0.005-0.5	> 3
Sulfur (S)	1100 - 2800	> 3,500
Vanadium (V)	0.02 - 0.85	> 2.5
Zinc (Zn)	25 - 50	> 150

Note:
(a) All concentrations given in µg/gm (ppm), air-dried (<40°C) weight for aerial portions of washed plant material approaching maturity, but not senescent. No particular elemental "accumulator" species are presumed to exist within the study area.

(b) "Elevated" levels do not represent necessarily concentrations toxic to animals consuming them; rather, they represent concentrations judged to be unexpected, given the present understanding of the area's soils, geology, climate, etc.

(c) Available data was insufficient to prepare these estimates.

Sources: Baker and Chesnin 1975, Chaney 1983, Chapman 1973, Dvorak et al. 1978, MultiTech and Stiller and Associates 1984a, Siegel 1974, Underwood 1977.

VI.2.2 Preliminary Criteria taken from Dollhopf et al. (1986)

CATEGORY	ELEMENT(PPM)			
	As	Cd	Pb	Zn
• Total, Phytotoxic	20(a)	50(a)	200(a)	500(b)
• Maximum for Forage(c)	50	0.5	30	500

Notes:

(a) As quoted from Dollhopf et al. (1986): "Support of scientific literature allows a high degree of confidence that this value will adversely affect crop yield of most species under all soil conditions".

(b) As quoted from Dollhopf et al. (1986): "Scientific literature supports this value as safe for most species under most soil conditions".

(c) Taken from the National Research Council's 1980 publication entitled Mineral Tolerance of Domestic Animals.

VI.2.3. Table 4.5-10 of the Work Plan (MultiTech and Stiller and Associates 1984a)

TABLE 4.5-10.--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART B. DIETARY AND DOSAGE INFORMATION

Element	Livestock Species	Diet Type[b]	Concentration (Range) in Diet (ppm)[d]	Toxic Dosage Acute (mg/kg)	Toxic Dosage Chronic (mg/kg-day)
Arsenic	Cattle	Normal	~0.25	N/A[e]	N/A[e]
		Toxic	>350	750	7.5-10
	Horses	Normal	U[c]	N/A	N/A
		Toxic	>200	~650	3.3-5.5
	Sheep	Normal	U	N/A	N/A
		Toxic	10-1000	11-220	U
Cadmium	Cattle	Normal	0.01-0.5	N/A	N/A
		High	5.0	N/A	N/A
		Toxic	-	-	-
		• acute	2000-3000	U	N/A
		• chronic	50-500	N/A	U(>10?)
	Horses	Normal	U	N/A	N/A
		Toxic	U	U	U
	Sheep	Normal	<0.5	N/A	N/A
		High	5.0	N/A	N/A
		Toxic	50-500	U	U
Copper	Cattle	Normal	10-50	N/A	N/A
		Toxic	>115	40-800	~3.5
	Horses	Normal	U	N/A	N/A
		Toxic	800	U	U
	Sheep	Normal	5-10	N/A	N/A
		Toxic	>10	20-50	>3
Lead	Cattle	Normal	5-15	N/A	N/A
		Toxic	5-300	200-800	3-5
	Horses	Normal	1-30	N/A	N/A
		Toxic	80-1000	900	2.4-7
	Sheep	Normal	<1-3	N/A	N/A
		Toxic	5-300	20-80	0.3-3
Molybdenum	Cattle	Normal	0.5-3.5	N/A	N/A
		Toxic	5-6 (Cu=8-11) Sheep: 10-12, where Cu=8-11)	<2:1 Cu:Mo	2.1-3.1 (Cu:Mo)

TABLE 4.5-10.--TRACE ELEMENTS IN LIVESTOCK EVALUATION CRITERIA (CONTINUED)

PART B. DIETARY AND DOSAGE INFORMATION

Element	Livestock Species	Diet Type	Concentration (Range) in Diet (ppm)[d]	Toxic Dosage Acute (mg/kg)	Toxic Dosage Chronic (mg/kg-day)
Zinc	Cattle	Normal	50-100	N/A	N/A
		High	1000-5000	N/A	N/A
		Toxic	>5000	20000	U
	Horses	Normal	40-100	N/A	N/A
		High	U	N/A	N/A
		Toxic	3600	>90	<60
	Sheep	Normal	50-100	N/A	N/A
		High	800-1000	N/A	N/A
		Toxic	2000	180	20

Notes: (b) Diet type defined as follows: "Normal" is used where deficiencies are unknown, and indicates generally accepted background concentrations (of a given element). "High" refers to element levels that are elevated well above normal, but which are not necessarily toxic. "Toxic" is used for those elemental concentrations at which subclinical, clinical, or pathological signs of toxicity would be expected to occur (Puls 1981).

(c) "U" designates a value either unavailable at the time of compiling the literature, or which is presently unknown.

(d) Dietary levels are presented on a dry weight basis.

(e) "N/A" means not applicable.

Sources: Bartik and Piskac 1981, Clarke et al. 1981, Lewis 1972, Lillie 1972, Parada 1981, Penumarthy et al. 1980, Puls 1981, Underwood 1977.

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SILVER BOW CREEK REMEDIAL INVESTIGATION
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ATTACHMENT VII

pH-Eh STABILITY DIAGRAMS

VII.1 = As/P
VII.2 = Cd
VII.3 = Cu
VII.4 = Fe/S
VII.5 = Mn
VII.6 = Pb
VII.7 = Zn

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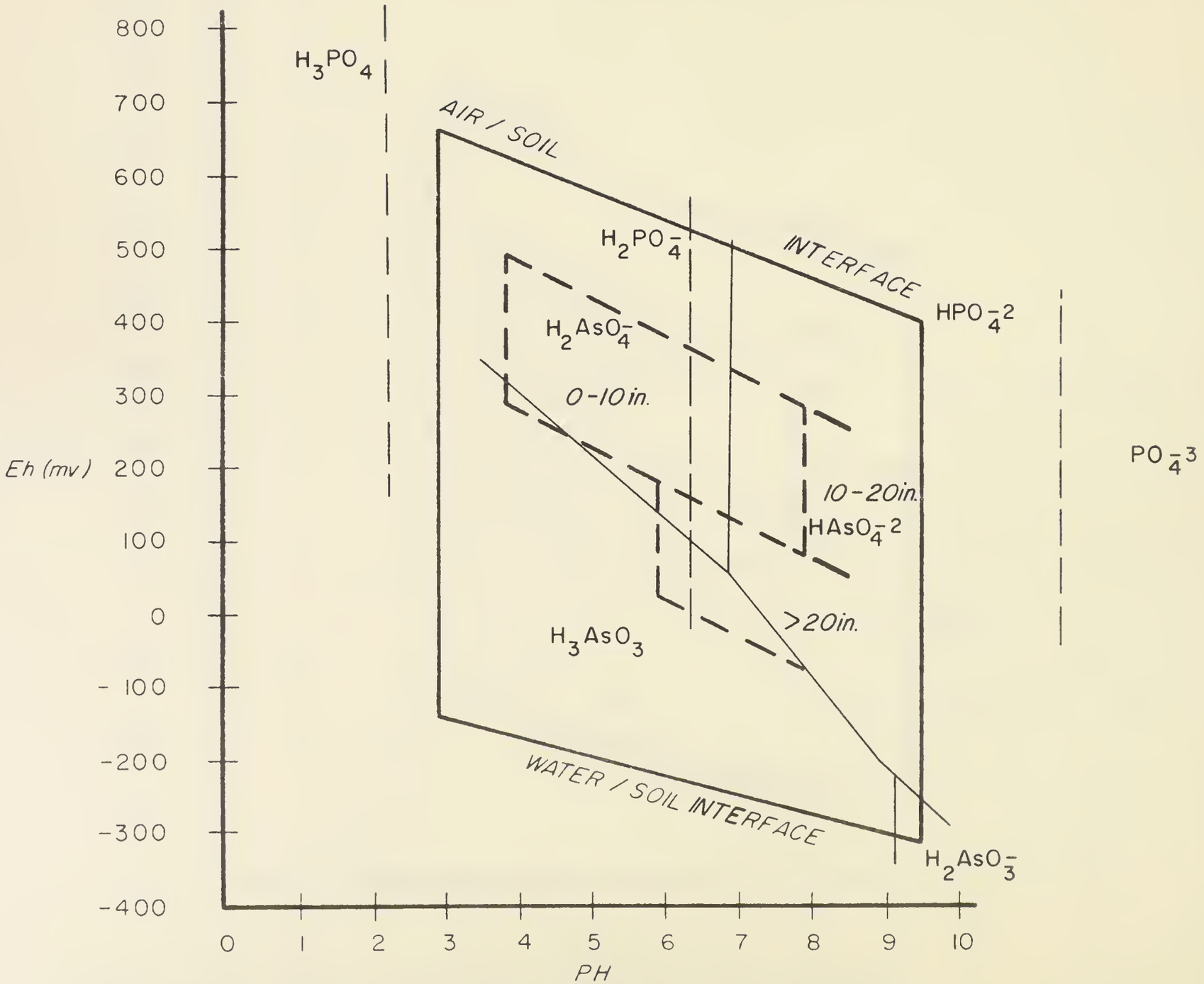
ATTACHMENT VII

INTRODUCTION

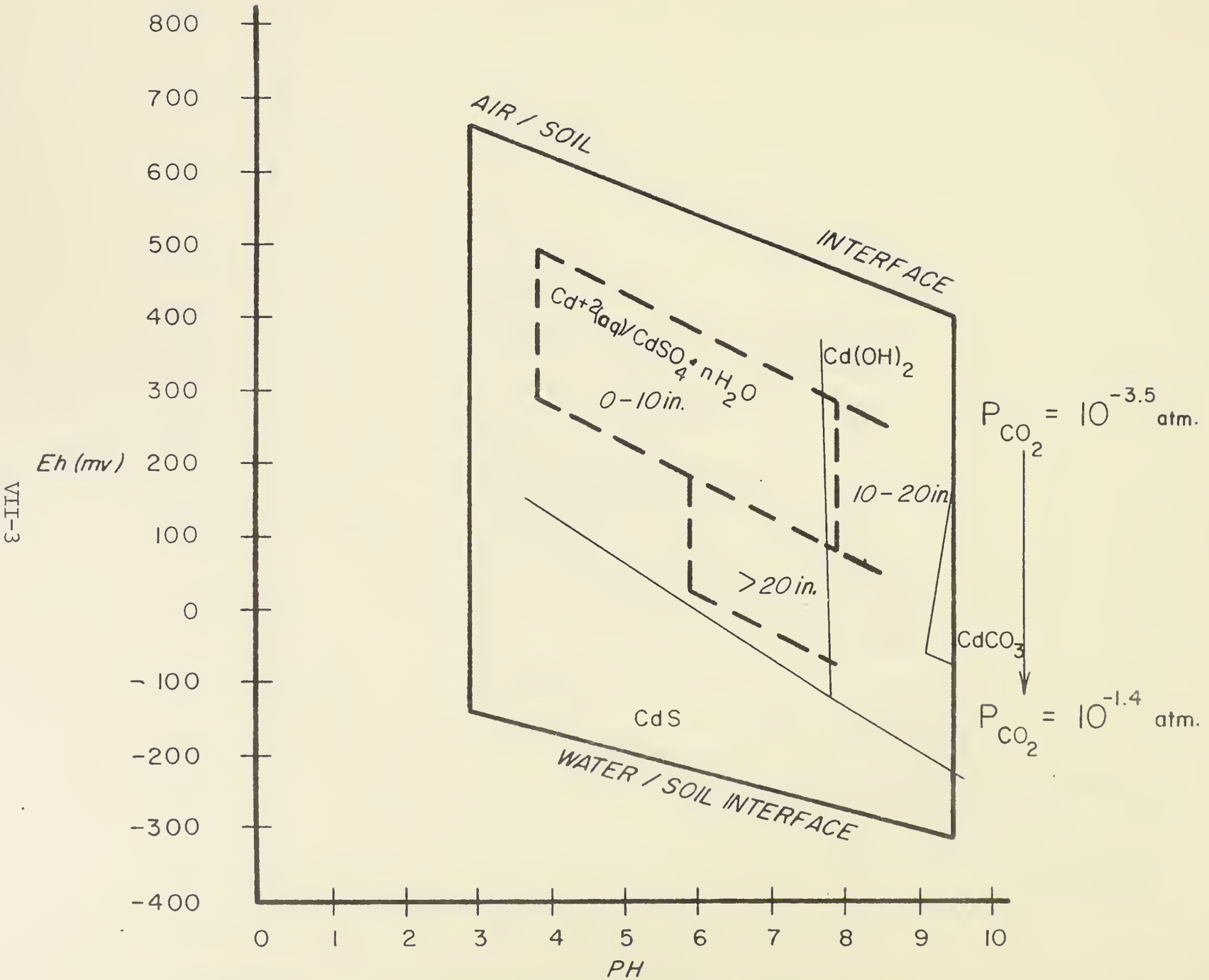
The probable chemical speciation of each heavy metal was assessed by constructing the following pH-Eh stability diagrams. This effort utilized the Agriculture Investigation's pH data and Tetra Tech's (1985) Eh data. The latter information fell within the expected range for moist soils in the Deer Lodge Valley (Becking *et al.* 1960), so independent measurement for this parameter was judged unnecessary.

The following assumptions also were made: (1) a CO_2 concentration gradient ranging from normal atmospheric conditions ($10^{-3.5}$atm.) to a soil solution essentially saturated ($10^{-1.4}$atm.) with CO_2; (2) constant temperature and pressure of 25°C and 1 atm.; (3) total dissolved carbonate concentration of 600 ppm and total dissolved sulfur activity ranging from 10^{-3} to 10^{-1}; and (4) dissolved manganese concentrations ranging from 10^{-6} to 10^{-2}M.

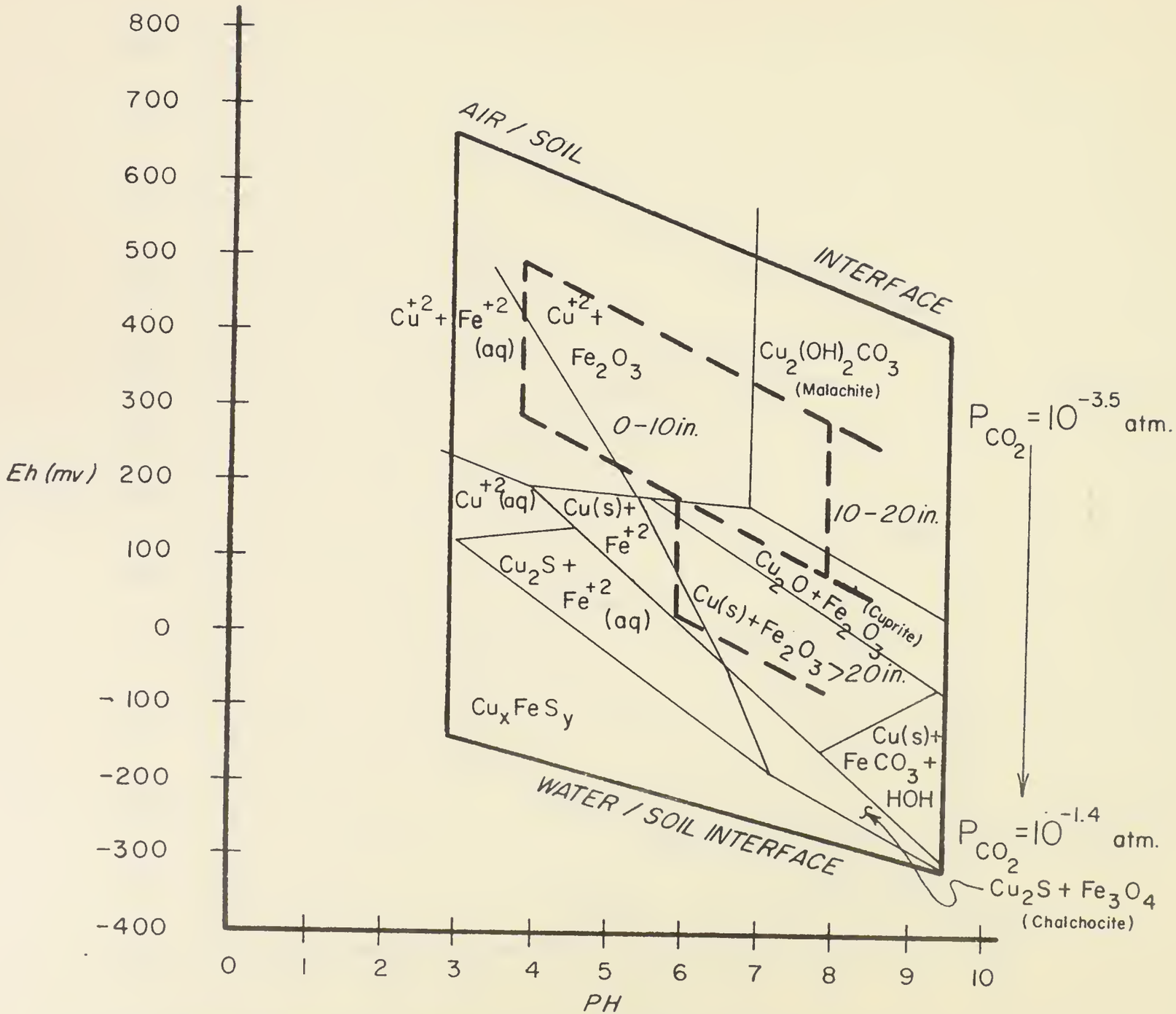
The three major technical references utilized to construct these diagrams are those by Garrels and Christ (1965), Schmitt (1962), and Brady (1974).



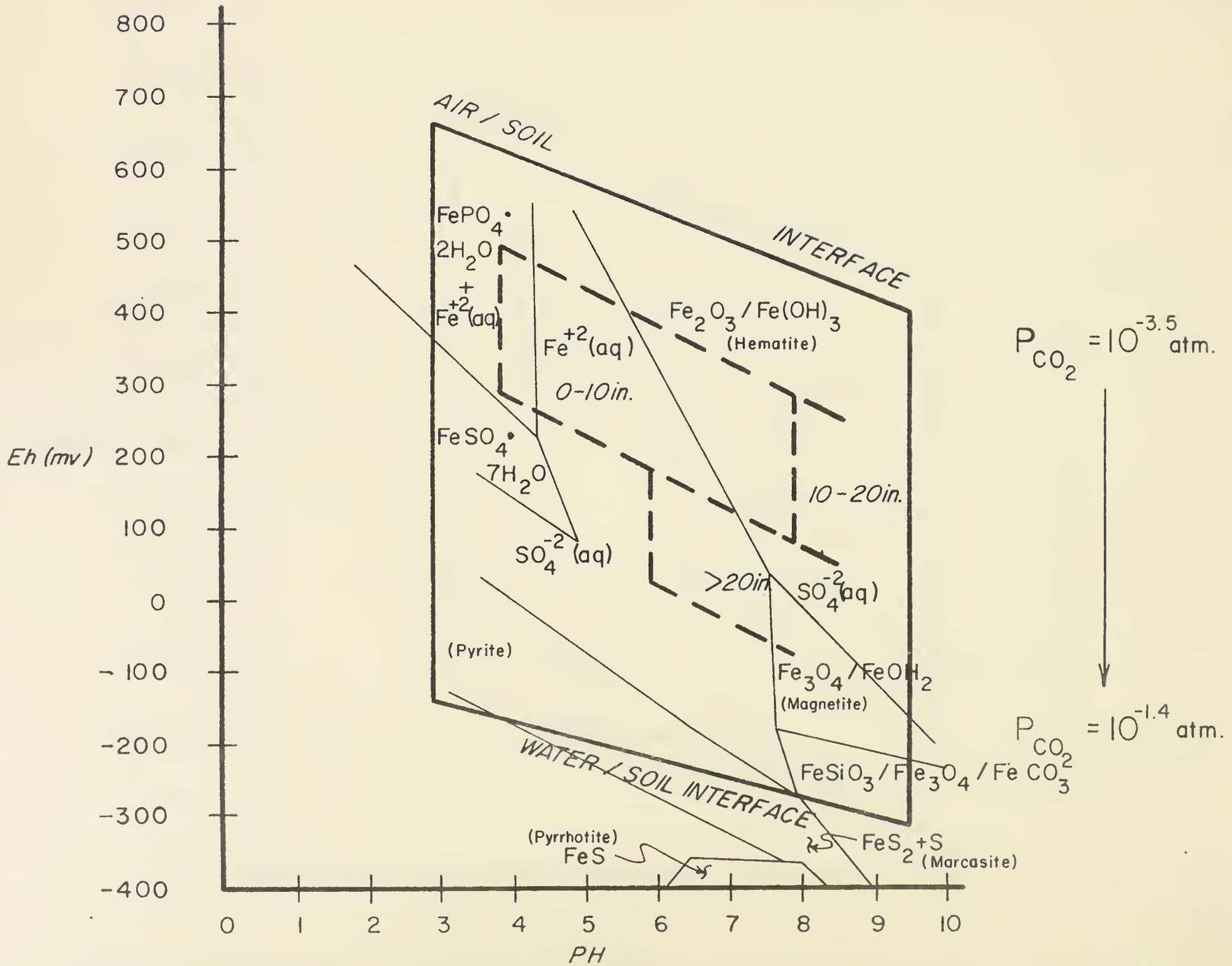
ATTACHMENT VII-1 STABILITY DIAGRAMS FOR ARSENIC AND PHOSPHORUS



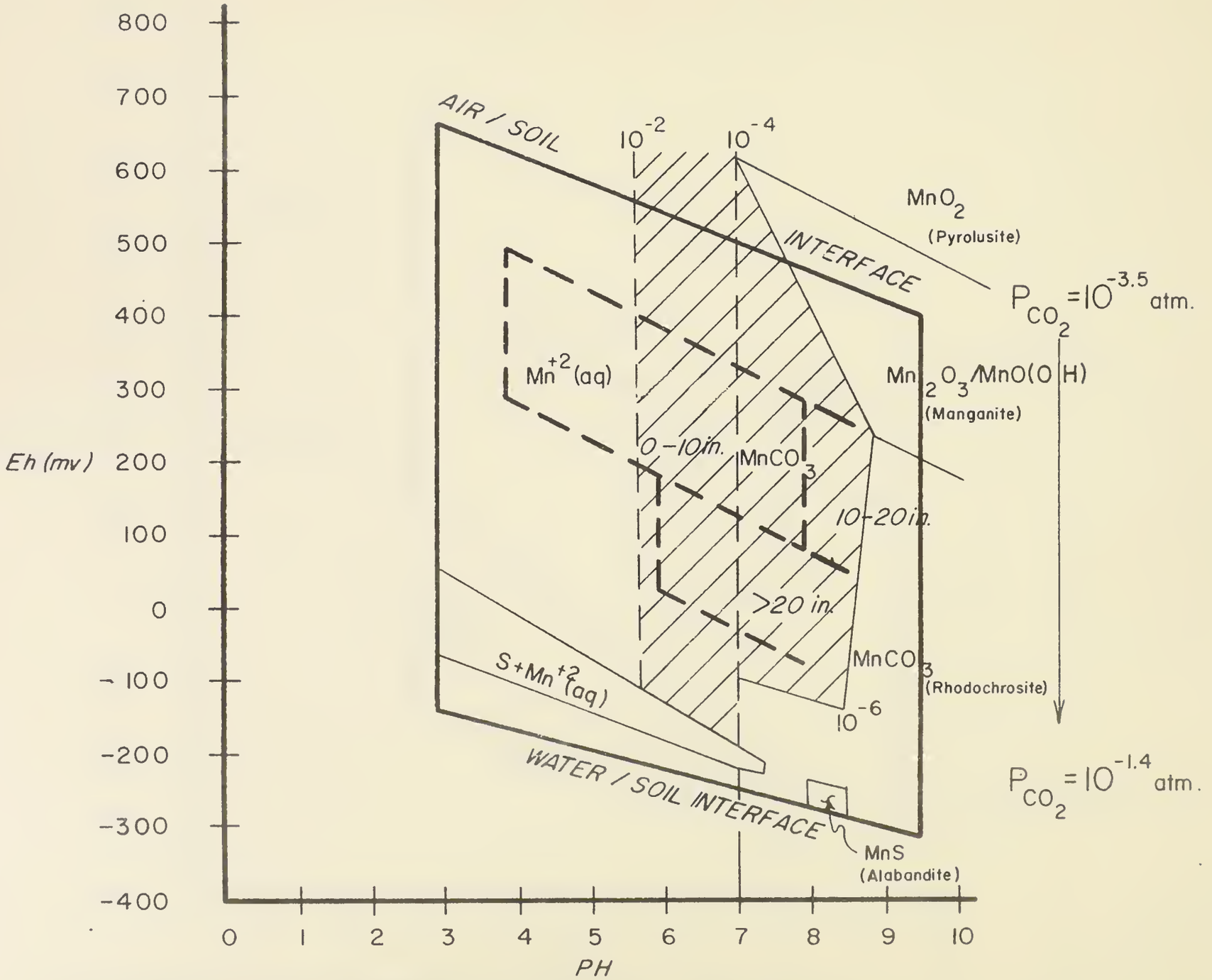
ATTACHMENT VII-2 STABILITY DIAGRAM FOR CADMIUM



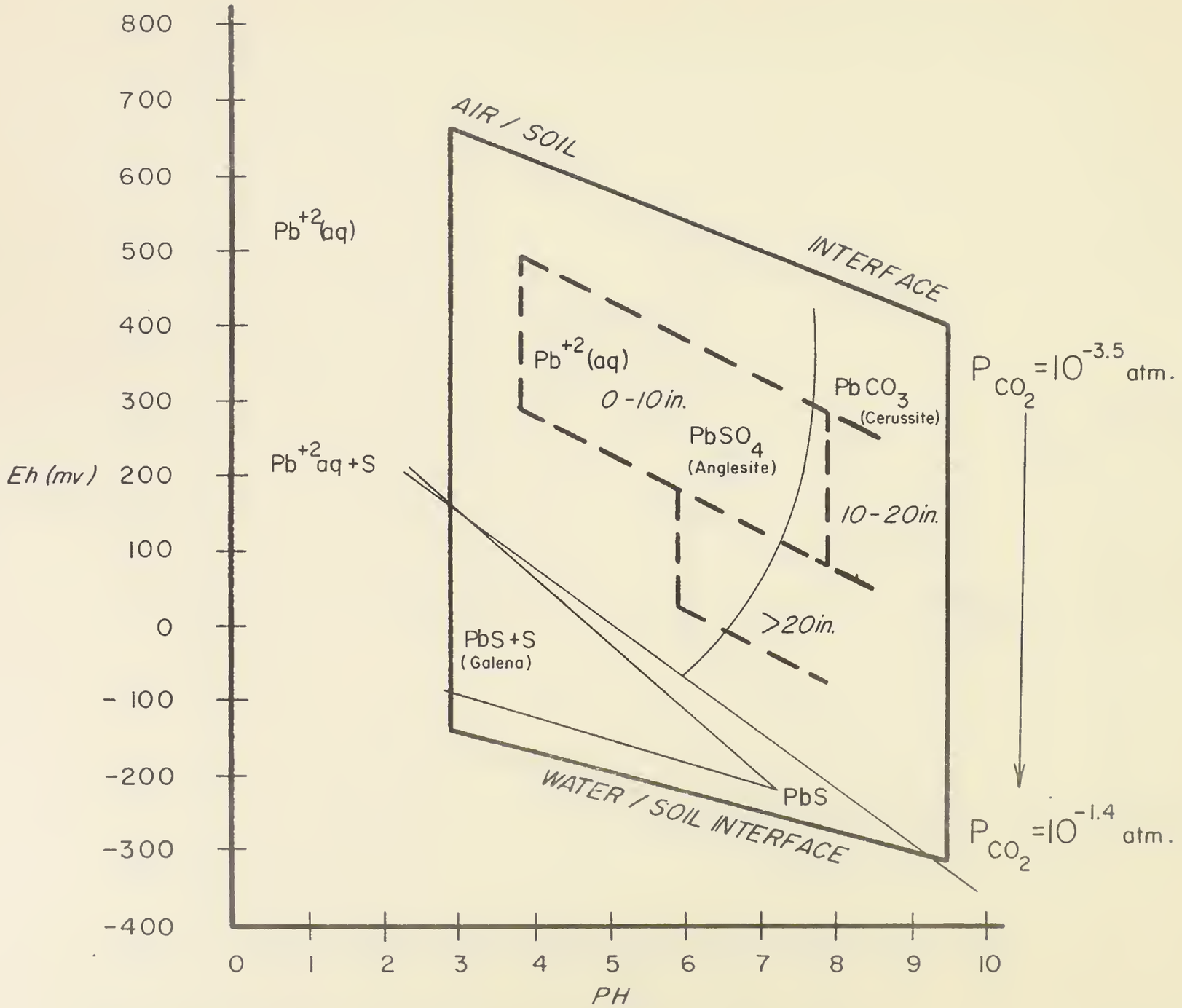
ATTACHMENT VII-3 STABILITY DIAGRAM FOR COPPER



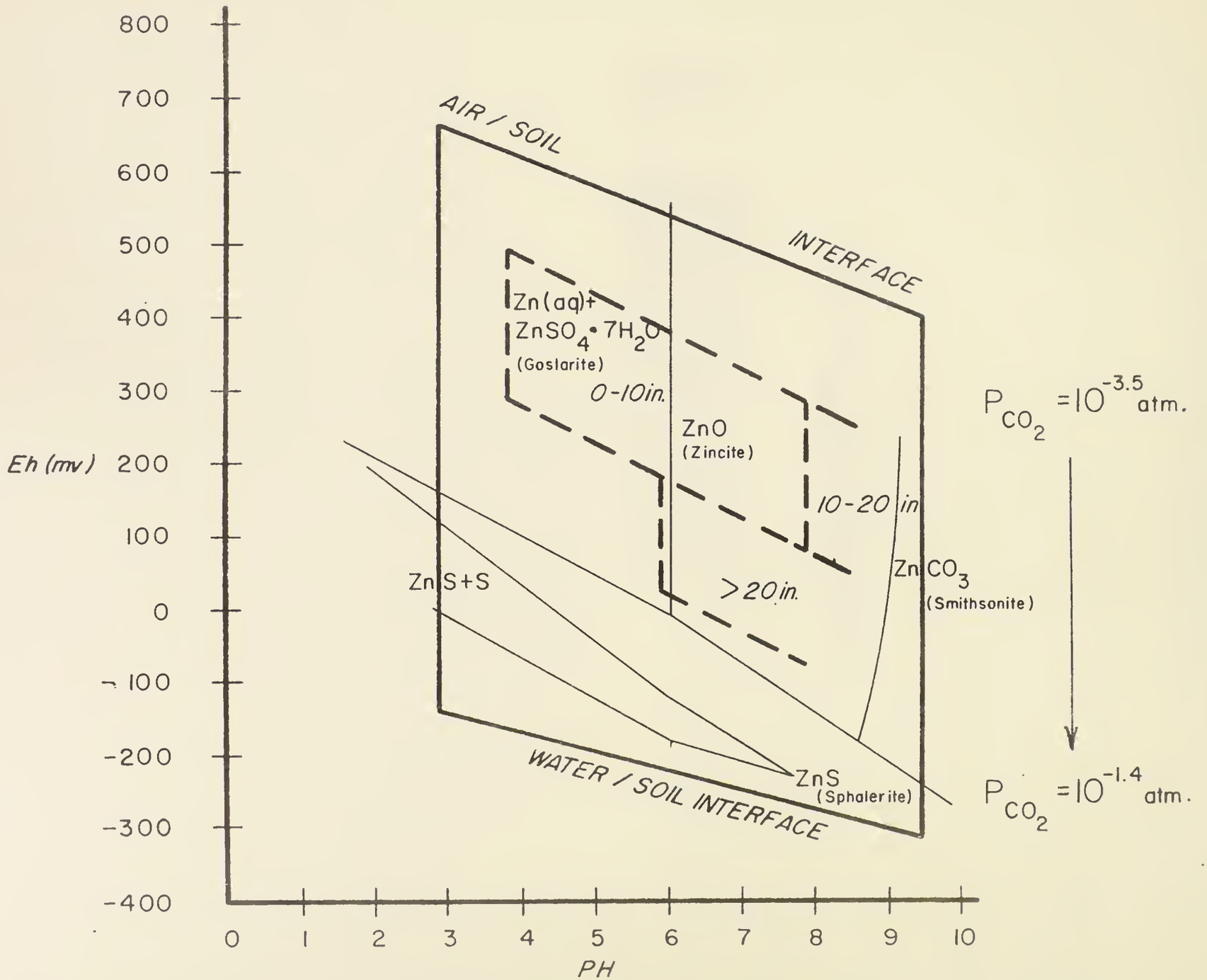
ATTACHMENT VII-4 STABILITY DIAGRAMS FOR IRON AND SULFUR



ATTACHMENT VII-5 STABILITY DIAGRAM FOR MANGANESE



ATTACHMENT VII-6 STABILITY DIAGRAM FOR LEAD



ATTACHMENT VII-7 STABILITY DIAGRAM FOR ZINC

DRAFT

SILVER BOW CREEK REMEDIAL INVESTIGATION
AGRICULTURE INVESTIGATION

ATTACHMENT VIII

SITE SOIL PROFILE DESCRIPTION
(IN DOWNSTREAM ORDER)

VIII.1 THURMOND'S SITES: A10 and A11
VIII.2 KONDA'S SITES: A1, A2, and A3
VIII.3 PETERSON'S SITES: T12, T13, T14, T15, T16, and T17
VIII.4 SPANGLER'S SITES: A6 and A7
VIII.5 FORSEN'S SITES: A12 and A13
VIII.6 DUTTON'S SITE: A9

MultiTech

VIII.1 THURMOND'S SITES: A10 and A11

General Description

One "upgradient:downgradient" sampling pair was utilized; the respective field identification numbers are A10 and A11. Site A10, upper pasture, is located in the SE 1/4 NE 1/4 SE 1/4 NW 1/4 quarter of Section 20, T3NR8W in Silver Bow County. Site A11, lower pasture, is located approximately 30 ft east of Silver Bow Creek in the NW 1/4 SW 1/4 NE 1/4 NW 1/4 quarter of the above section. The two sites are shown in Map 3-1 in the text. Published aerial coverage for sites A10 and A11 can be found in the USGS orthophotoquadrangle sheets entitled "Butte South, Mont." (1977) and "Ramsay, Mont." (1977), respectively.

Site A10

Site A10 is situated midslope on a moderately sloping (8%), north facing alluvial fan at approximately 5450 ft. elevation (mean sea level--msl). Annual precipitation is approximately 12 in., while the site's frost-free season probably ranges from 70 to 90 days per year (USDA 1979, maps V-1, V-2). Site drainage is well to excessive, permeability is medium, and existing erosion condition is moderate. The site's perennial vegetation (including *Trifolium*, *Poa* and *Bromus* spp.) is irrigated from a well, and is used for livestock forage.

The probable soil series is "Tally, cool variant" and is classified taxonomically as being a coarse-loamy, mixed Typic Haploboroll (USDA 1975). Dr. Schafer determined this classification by comparing field observations against data found in both the unpublished soils mapping legend for the Deer Lodge Valley (USDA SCS 1984) and published series description sheet. This classification process was utilized at all Phase One sampling sites. The A1 horizon sampled is described in VIII-1.

The soil's geologic parent material was not sampled here or at any other of the Phase One sites. However, the probable type is alluvial and lacustrine deposits, including volcanic ash and mudflow materials, of Tertiary age (Smedes 1967, 1968).

Site A11

Site A11 is situated on a gently sloping (2%), west-northwest facing alluvial terrace at approximately 5370 ft. elevation (msl). Site drainage is poor, permeability is slow to medium, and erosion condition is moderate. The site's perennial vegetation is irrigated using water pumped from Silver Bow Creek; land use is pasture for cattle.

Although no soil series could be determined from the unpublished legend, it was classified taxonomically as being a coarse-loamy, mixed Typic Fluvaquent (USDA 1975). The AC1 horizon sampled is described in Table VIII-2. This horizon included an admixture of

mill tailings and materials of alluvial origin. This horizon overlay flood-reworked sediments that included silt lenses, gravelly sand and pockets of what appeared to be railroad ballast. At time of sampling (6/27/85), depth to water table was 17 inches.

TABLE VIII-1
A10

SITE DESCRIPTION

SOIL SERIES: TALLY(COOL) -A SITE NUMBER: 57 COUNTY : SILVER BOW
TAXON : COARSE-LOAMY, MIXED TYPIC HAPLOBOROLLS (135D)
LOCATION : THURMOND UPPER PASTURE
SE 1/4, NE 1/4, SE 1/4, NW 1/4 SECTION 20 T3N R8W

DATE : 06/27/85 1220 ELEVATION : 5450F 1661M PRECIP : 11.8 IN 299.7MM
MATERIAL : crystl. alluv. VEGETATION :peren. forage LAND USE:irrigated hay
DRAINAGE : well to excess PERMEABILITY:medium EROSION :moderate
POSITION : midslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 8% 4.5 D ASPECT :N

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	105	0- 5	10YR 3/4	10YR 5/4	1	2	243	3323	542	111	0.0	1	21

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:

HORIZON:

TABLE VIII-2
All

SITE DESCRIPTION

SOIL SERIES: (All) SITE NUMBER: 58 COUNTY : SILVER BOW
TAXON : COARSE-LOAMY, MIXED TYPIC FLUVAQUENTS
LOCATION : THURMOND LOWER PASTURE 30 FEET EAST OF SBC.
NW 1/4, SW 1/4, NE 1/4, NW 1/4 SECTION 20 T3N R8W

DATE : 06/27/85 1309 ELEVATION : 5370F 1636M PRECIP : 11.7 IN 297.2MM
MATERIAL : tailings VEGETATION :peren. forage LAND USE:pasture
DRAINAGE : poor PERMEABILITY:slow to mediumEROSION :moderate
POSITION : level slope LANDFORM :terrace NUM.HOR.: 1
SLOPE : 2% 1.2 D ASPECT :WNW

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
AC1	106	0- 9	10YR 4/3	10YR 5/4	fsl	0	223	2222	542	111	7.0	1	11

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
NINE INCHES TAILINGS OVER FLOOD DEPOSITS.
WATER TABLE AT 17 INCHES.
HORIZON:
AC1: STRATIFIED WITH 7.5 YR 3/6 AND N/6 MATERIAL.

VIII.2 KONDA'S SITES: A1, A2, and A3

General Description

Three sites, identified as A1 through A3, were sampled within Konda's field. Based on site reconnaissance, these sites appear to represent a "contamination gradient". This gradient ranged from the relatively uncontaminated upland (A1) site to the apparently contaminated flood channel (A3) site. Sites A1 and A2, situated above and below the inactive Miles Ditch, respectively, are both located in the SW 1/4 NW 1/4 SW 1/4 NW 1/4 quarter of Section 16, T3NR9W in Silver Bow County. Site A3 is located in the SE 1/4 SW 1/4 SW 1/4 NW 1/4 quarter of the above section. All three sites are shown in Map 3-2. Published aerial coverage for these sites can be found in the USGS orthophotoquadrangle sheet entitled "Ramsay, Mont." (1977).

Site A1

Site A1 is located on a gently sloping (2%), south-southwest facing footslope of an alluvial fan at approximately 5280 ft. elevation (msl). The site is located adjacent to foothills (or out-crops) of volcanic origin, probably representing the Lowland Creek Formation of late Tertiary age. Annual precipitation is approximately 12 in., while the frost-free season probably ranges from 70 to 90 days per year (USDA 1979, Maps V-1, V-2). The well-drained site exhibits medium permeability and is slightly eroded. The vegetation

present is representative of shallow, saline, rangeland sites observed also in the Deer Lodge Valley (Ross and Hunter 1976). The predominant uses of these subirrigated lands is forage production and livestock grazing.

The probable soil series is "Straw, cool variant" and is classified taxonomically as being a fine-loamy, mixed Cumulic Haploboroll (USDA 1975). The profile description, prepared by Dr. Schafer, is found as Table VIII-3. The probable geologic parent material is Quaternary-aged alluvium (Smedes 1968).

Site A2

Site A2 is located on a nearly level (1%), south-southwest facing footslope of an alluvial fan at approximately 5280 ft elevation. Site drainage is moderate, permeability is medium, and the present erosion condition is slight. The predominance of sedge (Carex) and rush (Juncus) species indicates a wetland/subirrigated range site (Ross and Hunter 1976). Land use is subirrigated hay for livestock consumption.

Soil taxonomy is the same as for site A1. The A1 horizon sampled is described in Table VIII-4. The probable geologic parent material is Quaternary alluvium (Smedes 1968).

Site A3

Site A3 is located on level ground within an historic flood channel. Site drainage is poor to moderate, permeability is medium, and the present erosion condition is moderate. Salt efflorescence (on the soil surface) was common, and vegetative cover was about 50 percent. The chlorotic stands of Carex sp. and Basin wildrye (Elymus cinereus) sampled were located within and adjacent to these salt-affected areas.

The soil's taxonomic classification was not determined to the series level; however, it was identified as being a fine-loamy, mixed Typic Haplaquoll (USDA 1975). The profile description is given in Table VIII-5. Sandy, rust-colored mill tailings were observed commonly throughout the C2 (15-30 in.) horizon. The water table was encountered at a depth of 43 in., near the base of the buried A (IIA1) horizon.

TABLE VIII-3
A1

SITE DESCRIPTION

SOIL SERIES: STRAW(COOL) - SITE NUMBER: 51 COUNTY : SILVER BOW
TAXON : FINE-LOAMY MIXED CUMULIC HAPLOBOROLLS (25B)
LOCATION : NW CORNER OF KONDA PASTURE
SW 1/4,NW 1/4, SW 1/4, NW 1/4 SECTION 16, T5N R9W

DATE : 06/27/85 1515 ELEVATION : 5280F 1609M PRECIP : 11.3 IN 287.0MM
MATERIAL : crystl. alluv. VEGETATION :peren. forage LAND USE:subirr. hay
DRAINAGE : well PERMEABILITY:medium EROSION :slight
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 3
SLOPE : 2% 1.2 D ASPECT :SSW

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	107	0- 12	10YR 3/2	10YR 4/2	l	1	244	3323	762	342	0.0	l	31
B2	108	12- 22	10YR 3/3	10YR 5/3	fsl	0	254	2322	762	232	0.0	l	21
C1	109	22- 28	10YR 4/3	10YR 6/3	sl	1	111	2211	552	111	0.0	l	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
LOCATED JUST ABOVE MILES DITCH BELOW VOLCANIC OUTCROP

HORIZON:
A1: RECENT DEPOSIT FROM 0 TO 4 INCHES, DARK A1 4-12 INCHES

TABLE VIII-4

A2

SITE DESCRIPTION

SOIL SERIES: STRAW(COOL) - SITE NUMBER: 52 COUNTY : SILVER BOW
TAXON : FINE-LOAMY MIXED CUMULIC HAPLOBOROLLS (25B)
LOCATION : NW CORNER OF KONDA PASTURE
SW 1/4, NW 1/4, SW 1/4, NW 1/4 SECTION 16 T3N R9W

DATE : 06/27/85 1540 ELEVATION : 5280F 1609M PRECIP : 11.3 IN 287.0MM
MATERIAL : crystl. alluv. VEGETATION :sedge & rush LAND USE:subirr. hay
DRAINAGE : moderate PERMEABILITY:medium EROSION :slight
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 1% 0.6 D ASPECT :SSW

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	110	0- 6	10YR 3/2	10YR 4/2	1	1	344	3323	772	242	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
JUST BELOW MILES DITCH PAIRED WITH SITE A1

HORIZON:
A1: HIGH OM %

TABLE VIII-5
A3

SITE DESCRIPTION

SOIL SERIES: (A3) SITE NUMBER: 53 COUNTY : SILVER BOW
TAXON : FINE-LOAMY, MIXED TYPIC HAPLAQUOLL (11A)
LOCATION : SW END OF KONDA FIELD ALONG RAILROAD TRACKS
SE 1/4, SW 1/4, SW 1/4, NW 1/4 SECTION 16 T3N R9W

DATE : 06/27/85 1625 ELEVATION : 5260F 1603M PRECIP : 11.3 IN 287.0MM
MATERIAL : alluvium VEGETATION :sedge & rush LAND USE:disturbed land
DRAINAGE : poor to mod. PERMEABILITY:medium EROSION :moderate
POSITION : level slope LANDFORM :floodplain NUM.HOR.: 3
SLOPE : 0% 0. D ASPECT :

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR CONS RT PR dsk dms asl ask	pH	EFF	BND
C1	111	0- 15	7.5YR3/6	7.5YR5/6	1	0	254 4323 742 111	8.0	1	51
C2	112	15- 30	7.5YR3/6	7.5YR5/6	1	0	254 4323 542 111	8.0	1	21
IIA1	113	15- 46	10YR 3/2	10YR 4/2	sil	0	111 4323 442 111	8.0	1	31

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
SALT EFFLORESCENCE ON SURFACE WITH 50% BARE GROUND

HORIZON:

C2: COMMON INCLUSIONS OF SANDY RUST-COLORED TAILINGS
IIA1: WATER TABLE AT 43 INCHES, SAND BELOW 45 INCHES.

VIII.3 PETERSON'S SITES: T12, T13, T14, T15, T16 AND T17

General Description

Three site pairs relevant to both the tailings and agricultural RI studies were sampled at Peterson's. The locations are as follows:

- T12 (upgradient): T13 (downgradient) pair situated in the SW 1/4 and SE 1/4 tracts, respectively, of the SE 1/4 SE 1/4 SE 1/4 quarter of Section 35, T4NR10W, Silver Bow Co.;

- T14 (upgradient): T15 (downgradient) pair situated in the SW 1/4 and SE 1/4 tracts, respectively, of the NE 1/4 SE 1/4 NW 1/4 quarter of Section 35, T4NR10W, Deer Lodge Co.; and

- T17 (upgradient): T16 (downgradient) pair situated in the SW 1/4 and NE 1/4 tracts respectively, of the NW 1/4 NW 1/4 NE 1/4 quarter of Section 35, T4NR10W, Deer Lodge Co.

These site pairs are shown in Map 3-3. Published aerial coverage can be found in the USGS orthophotoquadrangle sheet entitled, "Opportunity, Mont." (1977).

T12:T13 Pair

Both of these sites are situated on a gently sloping (1%), north-facing footslope of a low alluvial terrace at approximately 5100

ft elevation (msl). Annual precipitation ranges from 12 to 14 in., while the frost-free season probably varies from 70 to 90 days (USDA 1979; Maps V-1, V-2). Site T12's drainage is poor to moderate, permeability is slow, and present erosion (condition) is nil. For site T13, drainage is poor, permeability is medium and the erosion condition is severe. The predominance of sedge (Carex) and rush (Juncus) species at site T12 indicates a wetland/subirrigated range site (Ross and Hunter 1976). Land use is for pasture. At site T13, vegetative cover was less than 5%; scattered stands of sedge and rush species occurred on slightly elevated ground (relative to the denuded, eroding areas).

Soils' taxonomic classification was not determined to the series level at either site. However, they belong to the clayey-over-sandy, mixed Aridic Argiboroll subgroup (USDA 1975). The profile descriptions for sites T12 and T13 are found as Tables VIII-6 and VIII-7, respectively. The probable geologic parent material (at both sites) is alluvium of Quaternary age (Alt and Hyndman 1976).

T14:T15 Pair

Site T14 is situated on a gently sloping (4%), southeast facing footslope of an alluvial fan at approximately 5080 ft elevation. The site is well drained, permeability is medium to rapid, and erosion condition is severe. Land use was irrigated alfalfa hay production. Although an "upgradient" site, evidence of an old lateral channel from the Yellow Ditch was found slightly uphill

from the sampling site. A veneer of small gravel and coarse granitic sand, plus acid accumulation (denuded) spots were present alongside the lateral channel; these materials could represent overflow from this old channel. Alfalfa production appeared to be poor where sampled, with existing plants not nodulating.

The soil series was identified as "Anaconda", a fine-loamy, mixed Aridic Haploboroll (USDA 1975). A description of the A1 (0-4 in.) horizon sampled is presented in Table VIII-8.

Site T15 is located on a gently sloping (3%) northwest facing footslope of an alluvial fan at approximately 5080 ft. elevation. Site drainage is poor to moderate, permeability is slow-to-medium and present erosion condition is moderate. Land use was irrigated oats production.

Those plants situated along the margin of the swale (wherein soils were sampled) were stunted and had yellow-tipped leaves with green veins. Such chlorosis hypothetically is a result of Zn induced Cu-deficiency.

Although no soil series was identified, it was classified taxonomically as being a fine-loamy, mixed Aquic Haploboroll (USDA 1975). A description of the A1 (0-8 in.) horizon sampled is presented in Table VIII-9.

T17:T16 Pair

Site T17 is situated on a gently sloping (3%), north-northeast facing footslope of an alluvial fan at approximately 5040 ft. elevation; it is also situated above an old lateral of the Yellow Ditch. Land use was irrigated alfalfa hay production; the stand appeared to be in good condition.

The soil series was identified as "Varney", a fine-loamy, mixed Aridic Argiboroll. A description of the A1 (0-5 in) horizon sampled is presented in Table VIII-10.

Site T16 is located on a gently sloping (2%), northeast facing footslope of an alluvial fan at approximately 5040 ft. elevation. Soils were sampled in a bare area alongside an old lateral from the Yellow Ditch. The first-year alfalfa planted there either died or did not nodulate; scattered stands of hoary cress (Cardaria draba) and field bindweed (Convolvulus arvensis) occurred within this generally denuded area. Irrigated alfalfa plants growing adjacent to the bare spot constituted the site's vegetation sample.

The soil series was identified as "Varney", a fine-loamy, mixed Aridic Argiboroll. A description of the A1 (0-5 in) horizon sampled is presented in Table VIII-11.

TABLE VIII-6
T12

SITE DESCRIPTION

SOIL SERIES: T12 SITE NUMBER: 12 COUNTY : SILVER BOW
TAXON : CLAYEY OVER SANDY, MIXED ARIDIC ARGIBOROLLS (129A)
LOCATION : ABOVE OLD DITCH E. OF LAGOON AT PETERSONS
SW 1/4, SE 1/4, SE 1/4, SE 1/4, SECTION 35, T4N, R10W

DATE : 06/28/85 1240 ELEVATION : 5100F 1554M PRECIP : 11.1 IN 281.9MM
MATERIAL : res. igneous VEGETATION :sedge & rush LAND USE:pasture
DRAINAGE : poor to mod. PERMEABILITY:slow EROSION :none
POSITION : footslope LANDFORM :terrace NUM.HOR.: 2
SLOPE : 1% 0.6 D ASPECT :N

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
O1	59	0- 5	10YR 3/1	10YR 4/1	fibrc	0	111	3311	772	111	0.0	1	21
IIC1	60	5- 17	10YR 4/1	10YR 5/1	ls	0	111	1111	361	111	0.0	1	13

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
5 INCH HISTIC HORIZON OVER SANDS AND OLD ARGILLIC HORIZON
ON FLOODPLAIN OF SBC
HORIZON:
O1: HISTIC HORIZON
IIC1: COARSE AND MEDIUM SAND OVER ERODED ARGILLIC HORIZON

TABLE VIII-7
T13

SITE DESCRIPTION

SOIL SERIES: T13 SITE NUMBER: 13 COUNTY : SILVER BOW
TAXON : CLAYEY OVER SANDY, MIXED ARIDIC ARGIBOROLLS (129A)
LOCATION : BELOW OLD DITCH, EAST OF PETERSON LAGOON.
SE 1/4, SE 1/4, SE 1/4, SE 1/4, SECTION 35, T4N, R10W

DATE : 06/29/85 1315 ELEVATION : 5100F 1554M PRECIP : 11.1 IN 281.9MM
MATERIAL : crystl. alluv. VEGETATION :bare ground LAND USE:pasture
DRAINAGE : poor PERMEABILITY:medium EROSION :severe
POSITION : footslope LANDFORM :terrace NUM.HOR.: 3
SLOPE : 1% 0.6 D ASPECT :N

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT acl	PR ask	pH	EFF	BND
C1	61	0- 3	10YR 3/3	10YR 5/3	sil	0	464	4323	111	346	5.5	1	12
IIO1	62	3- 10	10YR 2/2	10YR 4/2	1	5	111	3212	342	544	5.5	1	21
IIB2	63	10- 18	10YR 3/3	10YR 5/3	sl	40	111	3212	111	111	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
TERRACE ABOVE SBC, 2 INCHES CONTAMINATED SEDIMENT FROM IRRIGATION, BARE GROUND WITH SOME CAREX

HORIZON:
C1: LAYER OF SEDIMENT FROM IRRIGATION DITCH
IIO1: DECOMPOSED FIBRIC LAYER BURIED BY SEDIMENT
IIB2: ABUNDANT SANDS AND GRAVEL

TABLE VIII-8
T14

SITE DESCRIPTION

SOIL SERIES: ANACONDA - T14 SITE NUMBER: 14 COUNTY : DEER LODGE
TAXON : FINE-LOAMY, MIXED ARIDIC HAPLOBOROLLS (35D)
LOCATION : PETERSON ALFALFA FIELD BELOW YELLOW DITCH LATERAL
SW 1/4, NE 1/4, SE 1/4, NW 1/4, SECTION 35, T4N, R10W

DATE : 06/28/85 1015 ELEVATION : 5080F 1548M PRECIP : 11.0 IN 279.4MM
MATERIAL : crystl. alluv. VEGETATION :irr. fieldcrop LAND USE: irrigated hay
DRAINAGE : well PERMEABILITY: med. to rapid EROSION : severe
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 4% 2.3 D ASPECT :S 70DEG E

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
Ai	55	0- 4	10YR 3/2	10YR 5/2	sl	3	11'	4312	572	111	5.5	!	55

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
BARE GROUND ALONG LATERAL, GRAVEL VENEER ON SURFACE.
FAILURE IN FIRST YEAR STAND, EXISTING PLANTS NOT NODULATED
HORIZON:
A1: ABUNDANT COARSE SAND, ACID SPOTS ON SURFACE (NEAR DITCH)

TABLE VIII-9
T15

SITE DESCRIPTION

SOIL SERIES: T15 SITE NUMBER: 15 COUNTY : DEER LODGE
TAXON : FINE-LOAMY, MIXED AQUIC HAPLOBOROLLS (535A)
LOCATION : PETERSON OAT FIELD-SWALE BELOW YELLOW DITCH
SE 1/4, NE 1/4, SE 1/4, NW 1/4, SECTION 35, T4N, R10W

DATE : 06/29/85 950 ELEVATION : 5080F 1548M PRECIP : 11.0 IN 279.4MM
MATERIAL : crystl. alluv. VEGETATION :irr. fieldcrop LAND USE:irrigated crop
DRAINAGE : poor to mod. PERMEABILITY:slow to medium EROSION :moderate
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 3% 1.8 D ASPECT :N 30DEG W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	56	0- 8	10YR 3/2	10YR 4/2	cl	0	254	4333	542	111	8.0	2	11

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
CHLOROTIC OATS, STUNTED, WHITICH YELLOE TIPS WITH GREEN VEINS. AFFECTED PLANTS ALONG SWALE (CU DEFICIENT?)

HORIZON:
A1: UNDERLIEING B HORIZON CAMBIC, HIGH O.M. % (AQUIC)

TABLE VIII-10
T17

SITE DESCRIPTION

SOIL SERIES: VARNEY - T17 SITE NUMBER: 17 COUNTY : DEER LODGE
TAXON : FINE-LOAMY, MIXED ARIDIC ARGIBOROLLS (36C)
LOCATION : PETERSON FIELD ABOVE LATERAL FROM YELLOW DITCH
SW 1/4, NW 1/4, NW 1/4, NE 1/4, SECTION 35, T4N, R10W

DATE : 06/28/85 1110 ELEVATION : 5040F 1536M PRECIP : 10.9 IN 276.9MM
MATERIAL : crystl. alluv. VEGETATION :irr. fieldcrop LAND USE: irrigated hay
DRAINAGE : well PERMEABILITY: medium EROSION : slight
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 3% 1.8 D ASPECT :NNE

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	58	0- 5	10YR 4/3	10YR 6/4	scl	0	344	4323	752	111	0.0	1	11

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
LOCATED ABOVE DITCH IN GOOD ALFALFA STAND. SOIL 20 INCHES TO ROCK AND FINER TEXTURED THAN T16.
HORIZON:

TABLE VIII-11
T16

SITE DESCRIPTION

SOIL SERIES: VARNEY - T16 SITE NUMBER: 16 COUNTY : DEER LODGE
TAXON : FINE-LOAMY, MIXED ARIDIC ARGIBOROLLS (36C)
LOCATION : LOWER PETERSON ALFALFA FIELD
NE 1/4, NW 1/4, NW 1/4, NE 1/4, SECTION 35, T4N, R10W

DATE : 06/28/85 1100 ELEVATION : 5040F 1536M PRECIP : 10.9 IN 276.9MM
MATERIAL : crystl. alluv. VEGETATION :irr. fieldcrop LAND USE: irrigated hay
DRAINAGE : well PERMEABILITY: medium EROSION : moderate
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 1
SLOPE : 2% 1.2 D ASPECT :NE

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR CONS RT PR gsk	dmsp	asl	ask	pH	EFF	BND
A1	57	0- 5	10YR 3/3	10YR 5/4	sl	5	254	3311	222	111	0.0	1	21

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervescence BND =boundary thickness,shape

SITE:
BARE AREA ALONG YELLOW DITCH LATERAL. FIRST YEAR ALFALFA DIED OR DID NOT NODULATE. WEEDY.
HORIZON:
A1: MAY BE SOME SEDIMENT FROM DITCH

VIII.4 SPANGLER'S SITES: A6 and A7

General Description

One "upgradient:downgradient" sampling pair was utilized; the respective field identification numbers are A6 and A7. Site A6 is located in the NE 1/4 SW 1/4 NE 1/4 NW 1/4 quarter of Section 30, T4NR9W in Silver Bow County. Site A7 is located below an abandoned Milwaukee Railroad trestle in the SW 1/4 SW 1/4 NE 1/4 NW 1/4 quarter of the above section. The two sites are shown in Map 3-4. Published aerial coverage of these sites can be found in the USGS orthophotoquadrangle sheet entitled "Opportunity, Mont." (1977).

Site A6

The site is situated on a gently sloping (4%), southwest facing lower midslope of an alluvial fan at approximately 5085 ft. elevation. Annual precipitation probably ranges from 12-to-14-inches, while the frost-free season probably ranges from 70 to 90 days per year (USDA 1979; Maps V-1, V-2). The well drained site exhibits medium premeability and moderate erosion conditions. The vegetation appears characteristic of a silty range foothills site (Ross and Hunter 1976); representative grass species include Agropyron spicatum, A. smithii and Elymus cinereus. The abundance of rubber rabbitbrush (Chrysothamnus nauseosus), knapweed (Centaurea maculosa) and leafy spurge (Euphorbia esula) indicates heavy grazing effects, at least historically. In addition, the presence of a small ditch

situated slightly uphill from the site implies these lands were irrigated in the past. Present land use is range for cattle and sheep.

The soil series is "Tally, cool variant" and is classified taxonomically as coarse-loamy, mixed Aridic Haploboroll (USDA 1975). The profile description is given in Table VIII-12. The probable geologic parent material is granitic rocks (possibly Butte quartz monzonite) of the Boulder Batholith (Alt and Hyndman 1976).

Site A7

The site is situated on a gently sloping (3%), southwest-facing footslope of an alluvial fan at approximately 5075 ft. elevation. It is well-to-excessively drained, permeability is rapid, and erosion condition is severe. The range site classification is probably the same as for A6. However, such a determination was difficult due to the very poor vegetative conditions. Plant cover is less than 20% and is characterized by scattered clumps of Basin wildrye and luxuriant leafy spurge; other species observed include needle-and-thread grass (Stipa comata) and bindweed. Present land use is cattle pasture.

The bare surface was hypothesized to be desert pavement resulting from wind erosion. Coarse granitic sand and fine gravel are abundant surficially. These materials represent either wind-blown

sands or sediment released from the old irrigation ditch, situated just above the site. The soil series is also "Tally, cool variant". The profile description is found in Table VIII-13.

TABLE VIII-12

A6

SITE DESCRIPTION

SOIL SERIES: TALLY(COOL) - SITE NUMBER: 54 COUNTY : SILVER BOW
TAXON : COARSE-LOAMY, MIXED ARIDIC HAPLOBOROLLS (135C)
LOCATION : ABOVE RAILROAD TRESTLE AT SPANGLERS NEAR SITE A7
SE 1/4, NE 1/4, NW 1/4 SECTION 30, T4N, R9W

DATE : 07/06/85 1610 ELEVATION : 5085F 1549M PRECIP : 10.6 IN 269.2MM
MATERIAL : crystl. alluv. VEGETATION :mixed midgrass LAND USE:range
DRAINAGE : well PERMEABILITY:medium EROSION :moderate
POSITION : lower midslope LANDFORM :alluvial fan NUM.HOR.: 3
SLOPE : 4% 2.3 D ASPECT :S 50DEG W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
C1	118	0- 5	10YR 3/2	10YR 5/3	ls	5	111	1111	742	111	0.0	1	21
IIA1	119	5- 12	10YR 3/2	10YR 5/3	s	20	111	1111	743	111	0.0	1	31
IIC1	120	12- 24	10YR 3/2	10YR 4/3	ls	0	111	2211	542	111	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
BASIN WILDRYE, AGSM, KNAPWEED. SITE IS ABOVE MAIN IRRIG.
DITCH AND IS LESS CONTAMINATED THAN A7. SMALL DITCH ABOVE.
HORIZON:
C1: VENEER OF SEDIMENT FROM OVERGRAZING (HICH CO. SAND %)
IIA1: ABUNDANT CO. SAND AND FINE GRAVEL

TABLE VIII-13
A7

SITE DESCRIPTION

SOIL SERIES: TALLY(COOL) - SITE NUMBER: 55 COUNTY : SILVER BOW
TAXON : COARSE-LOAMY, MIXED ARIDIC HAPLOBOROLLS (135C)
LOCATION : SPANGLER NORTH PASTURE NEAR RR. TRESTLE N OF I-90
NE 1/4, SW 1/4, NW 1/4 SECTION 30, T4N, R9W

DATE : 07/06/85 1640 ELEVATION : 5075F 1546M PRECIP : 10.6 IN 269.2MM
MATERIAL : crystl. alluv. VEGETATION :bare ground LAND USE:pasture
DRAINAGE : well to excess PERMEABILITY:rapid EROSION :severe
POSITION : footslope LANDFORM :alluvial fan NUM.HOR.: 4
SLOPE : 3% 1.8 D ASPECT :S 70DEG W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
C1	114	0- 5	10YR 3/3	10YR 5/3	ls	20	454	4311	246	746	0.0	1	12
IIA1	115	5- 15	10YR 3/2	10YR 4/3	ls	30	111	1111	242	111	0.0	1	21
IIC1	116	15- 25	10YR 4/3	10YR 5/3	s	0	111	1111	111	111	0.0	1	11
IIIA1	117	25- 37	10YR 3/2	10YR 4/2	l	15	111	3323	111	111	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
CONTAMINATED BY PAST IRRIGATION. BARE GROUND (80%) WITH
BASIN WILDRYE, AGSM, AND LARGE LEAFY SPURGE
HORIZON:
C1: PAVEMENT FROM WIND EROSION, HIGH CO.S AND GRAVEL %.

VIII.5 FORSEN'S SITES: A12 AND A13

General Description

One "upgradient:downgradient" sampling pair was utilized. The respective field identification numbers are A12 and A13; they are situated above and below the remains of the E. Valiton Ditch, respectively. Both sites are located in the NE 1/4 NE 1/4 SE 1/4 NE 1/4 quarter of Section 16, T7NR9W in Powell County. The sites are shown in Map 3-5. Published aerial coverage can be found in the USGS photoquadrangle sheet entitled "Dempsey, Mont." (1977).

Site A12

This site is situated upper midslope on a moderately sloping (8%), northwest facing alluvial fan at approximately 4600 ft elevation. Annual precipitation is about 12 in., while the site's freeze-free season probably ranges from 90 to 100 days (USDA 1979; Maps V-1, V-2). This well-drained site exhibits medium permeability and moderate erosion conditions. The vegetation is representative of a moderately grazed silty range foothills site. Grass species include Basin wildrye, bluebunch wheatgrass (Agropyron spicatum) and blue grama (Bouteloua gracilis); shrub species include wild rose (Rosa woodsii) and rubber rabbitbrush. Present land use is pasture.

The soil profile was classified taxonomically as a coarse-loamy, mixed Typic Haploboroll, eroded phase (USDA 1975). The profile sampled is described in Table VIII-14. Geologic parent material is probably coarse gravels of volcanic origin, overlying light gray, poorly consolidated bedded tuff (Ruppel 1961).

Site A13

Site A13 is an upper midslope site, situated on a moderately sloping (7%), northwest-facing alluvial fan about 2 ft lower in elevation than site A12. This well-drained site of medium permeability is severely eroded. Inspection of the remnants of the ditch indicated that it had been breached (during operation), consequently releasing large quantities of coarse sediment and water. These materials could have been laden with heavy metals, thus partly explaining the depauperate vegetation present on site. Vegetative cover was estimated visually as being approximately 20 percent and included such species as Basin wildrye, bluebunch wheatgrass, leafy spurge and thistles (Cirsium arvense). Present land use is pasture in very poor condition.

Soil taxonomy is the same as for site A12. A description of the profile sampled is found in Table VIII-15.

TABLE VIII-14
A12

SITE DESCRIPTION

SOIL SERIES: (A12) SITE NUMBER: 59 COUNTY : POWELL
TAXON : COARSE-LOAMY, MIXED TYPIC HAPLOBOROLLS, ERODED (135D)
LOCATION : FORESON PASTURE ABOVE TRACE OF EAST VALITON DITCH
NE 1/4, NE 1/4, SE 1/4 SECTION 16, T7N, R9W

DATE : 07/07/85 1135 ELEVATION : 4600F 1402M PRECIP : 11.8 IN 299.7MM
MATERIAL : mixed alluviumVEGETATION :mixed midgrassLAND USE:pasture
DRAINAGE : well PERMEABILITY:medium EROSION :moderate
POSITION : upper midslopeLANDFORM :alluvial fan NUM.HOR.: 3
SLOPE : 8% 4.5 D ASPECT :N 80 DEG W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
A1	121	0- 5	10YR 4/3	10YR 5/4	sl	0	442	4332	742	544	0.0	1	21
B2	122	5- 14	10YR 4/4	10YR 5/4	sl	0	254	3333	742	544	0.0	1	31
C1	123	14- 40	10YR 4/4	10YR 5/4	fsl	0	111	3312	542	111	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS - moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
VEGETATION: WILD ROSE, AGSM, BASIN WILDRYE.

HORIZON:

B2: CAMBIC B HORIZON (DUPLICATE SAMPLE 77)
C1: DUPLICATE SAMPLE 78

TABLE VIII-15
A13

SITE DESCRIPTION

SOIL SERIES: (A13) SITE NUMBER: 60 COUNTY : POWELL
TAXON : COARSE-LOAMY, MIXED TYPIC HAPLOBOROLLS, ERODED (135D)
LOCATION : FORESON PASTURE BELOW TRACE OF EAST VALITON DITCH
NE 1/4, NE 1/4, SE 1/4 SECTION 16, T7N, R9W

DATE : 07/07/85 1220 ELEVATION : 4600F 1402M PRECIP : 11.8 IN 299.7MM
MATERIAL : mixed alluviumVEGETATION :bare ground LAND USE:pasture
DRAINAGE : well PERMEABILITY:medium EROSION :severe
POSITION : upper midslopeLANDFORM :alluvial fan NUM.HOR.: 4
SLOPE : 7% 4.0 D ASPECT :N 70DEG W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	CONS dmsp	RT asl	PR ask	pH	EFF	BND
C1	124	0- 3	10YR 4/2	10YR 5/3	sl	20	111	1112	111	546	0.0	1	12
IIA1	125	3- 8	10YR 3/3	10YR 4/3	fsl	5	244	3212	111	111	0.0	1	31
IIB2	126	8- 18	10YR 4/4	10YR 5/5	fsl	0	111	3212	111	111	0.0	1	31
IIC1	127	18- 38	10YR 4/3	10YR 5/4	fsl	5	111	3212	111	111	0.0	1	66

COMMENTS

CF = coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
LARGE CONTAMINATED AREA BELOW DITCH.

HORIZON:
C1: DEPOSIT FROM IRRIG. DITCH, ROCK PAVEMENT SURFACE (DUPL.
IIA1: ABUNDANT MOISTURE UNLIKE A12 DRY THROUGHOUT. (DUPL #80

VIII.6 DUTTON'S SITE: A9

General Description

One unpaired site, identified as A9, was utilized here. The legal description is the NE 1/4 SW 1/4 NW 1/4 NE 1/4 quarter of Section 31, T10NR10W in Deer Lodge County. The site location is shown in Figure 3-6. Published aerial coverage can be found in the USGS photoquadrangle sheet entitled "Griffin Creek, Montana" (1976).

The site is situated on a nearly level (1%), west-facing wet meadow within the Clark Fork River floodplain at approximately 4320 ft elevation. Annual precipitation is approximately 12 in., while the annual freeze-free season probably ranges from 90 to 100 days (USDA 1979; Maps V-1, V-2). The poorly drained site exhibits medium permeability and slight erosion conditions. The vegetation appears to be representative of a moderately grazed, subirrigated/wetland range site. Grass species include Kentucky bluegrass (Poa pratensis and smooth brome; Carex spp. were also abundant. Present land use is irrigated hay for livestock forage.

The soil was classified taxonomically as a fine-loamy, mixed Typic Fluvaquent (USDA 1975). The soil profile sampled is described in Table VIII-16. The surface was bare and possessed salt efflorescence; the C1 horizon was identified as mill tailings overlaying an older A (IIA1) horizon. The rocks encountered at 26 in. may have been alluvial material of Quaternary age (Alt and Hyndman 1976).

TABLE VIII-16
A9
SITE DESCRIPTION

SOIL SERIES: (A9) SITE NUMBER: 56 COUNTY : DEER LODGE
TAXON : FINE-LOAMY, MIXED TYPIC FLUVAQUENTS
LOCATION : DUTTON RANCH NEAR GOLD CREEK
NE 1/4, SW 1/4, NW 1/4, NE 1/4 SECTION 31 T10N R10W

DATE : 06/26/85 1700 ELEVATION : 3900F 1188M PRECIP : 15.5 IN 393.7MM
MATERIAL : mixed alluviumVEGETATION :peren. forage LAND USE:irrigated hay
DRAINAGE : poor PERMEABILITY:medium EROSION :slight
POSITION : level slope LANDFORM :floodplain NUM.HOR.: 4
SLOPE : 1% 0.6 D ASPECT :W

PROFILE DESCRIPTION

HOR.	NO.	DEPTH (IN)	COLOR MOIST	COLOR DRY	TEXT	CF %	STR gsk	STR dmsp	CONS asl	CONS ask	pH	RT EFF	PR BND
A11	101	0- 5	10YR 4/3	10YR 5/4	fsl	0	232	2211	111	111	5.5	1	11
A12	102	5- 10	10YR 4/6	10YR 6/6	ls	0	111	1121	111	111	5.0	1	11
C1	103	10- 18	10YR 5/6	10YR 6/8	si	0	222	3212	111	111	4.5	1	11
IIA1	104	18- 26	10YR 3/2	10YR 3/3	sil	0	242	3222	572	222	6.0	1	22

COMMENTS

CF - coarse fragment (%) STR = structure grade, size, and kind
CONS = moist,dry,sticky,plastic consistence RT = root amount, size, location
PR =pore amount,size,kind EFF =effervesence BND =boundary thickness,shape

SITE:
SALTY ON SURFACE, BARE GROUND. SOIL IN ANO OLD OXBOW OF THE CLARK FORK. SOME CHLOROTIC POA, BRIN.

HORIZON:
A11: 0-3.5" 10YR 2/3 SiCL, 2.5-5" FSL
A12: SLIGHTLY STRATIFIED RECENT OVERBANK DEPOSIT.
C1: STRATIFICATIONS OF 7.5 YR 4/8, N/2, THIXOTROPIC
IIA1: ROCKS AT 26 INCHES, HIGH O.M. CONTENT.